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TRANSACTIONS

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

VOLUME III

Third Meeting, New York, N. Y., 1907
December 2 and 3

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August 30, 1905.

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OF

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1907–1908.

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Term expires at Annual Meeting of 1908.
KARL E. VESTERDAHL.....New York, N. Y.
Term expires at Annual Meeting of 1909.

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JOHN E. STARR.....New York, N. Y.
H. B. ROELKER.....New York, N. Y.
Terms expire at Annual Meeting of 1908.

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F. W. PILSBRY.....Chicago, Ill.
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Terms expire at Annual Meeting of 1909.

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THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

1906–1907.

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VICE-PRESIDENTS.

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Term expired at Annual Meeting of 1907.

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Term expires at Annual Meeting of 1908.

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Terms expired at Annual Meeting of 1907.

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EDGAR PENNEY.....Newburgh, N. Y.
H. B. ROELKER.....New York, N. Y.

Terms expire at Annual Meeting of 1908.

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Terms expire at Annual Meeting of 1909.

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SECRETARY.

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OF

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Terms expired at Annual Meeting of 1907.

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OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

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VICE-PRESIDENTS.

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P. D. C. BALL.....St. Louis, Mo.
Term expired at Annual Meeting of 1906.

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Terms expired at Annual Meeting of 1905.

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W. T. ROBINSON.....Philadelphia, Pa.
Terms expired at Annual Meeting of 1906.

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L. HOWARD JENKS.....New York, N. Y.
Terms expired at Annual Meeting of 1907.

TREASURER.

WALTER C. REID.....New York, N. Y

SECRETARY.

WILLIAM H. ROSS.....New York, N. Y.

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

CONSTITUTION.

NAME, OBJECT AND GOVERNMENT.

C 1. The title of this Society shall be "The American Society of Refrigerating Engineers."

C 2. The object of this Society is to promote the Arts and Sciences connected with Refrigerating Engineering.

C 3. The principal means for this purpose shall be the holding of meetings for the reading and discussion of appropriate papers, and for social intercourse; the publication and distribution of its papers and discussions; and the maintenance of a library of data on refrigeration.

C 4. The Society shall be governed by this Constitution, and by By-Laws and Rules in harmony therewith.

C 5. The Society shall be organized as a Corporation under the laws of the State of New York.

MEMBERSHIP.

C 6. Persons connected with the Arts and Sciences relating to Refrigerating Engineering may be eligible for admission into the Society.

C 7. The membership of the Society shall consist of Members, Associates and Juniors. Members and Associates are entitled to vote and to hold office. Juniors shall not be entitled to vote nor to be officers of the Society, but shall be entitled to the other privileges of membership.

C 8. Members and Associates are entitled to vote on all questions before any meeting of the Society, in person or by proxy, given to a voting member in writing. A proxy shall not be valid for a greater time than six months.

C 9. A Member shall be twenty-six years of age or over. He must have been so connected with Refrigerating Engineering as to be competent as a designer or as a constructor, to take responsible charge of work in his branch of Refrigerating Engineering, or he

must have served as a teacher of Refrigerating Engineering for more than five years.

C 10. An Associate shall be twenty-six years of age or over and shall be so connected with Refrigerating Engineering as to be competent to take charge of engineering work, or to co-operate with Refrigerating Engineers.

C 11. A Junior shall be twenty-one years of age or over. He must have had such Refrigerating Engineering experience as will enable him to fill a responsible subordinate position in Refrigerating Engineering work, or he must be a graduate of an engineering school.

C 12. The rights and privileges of every Member, Associate and Junior shall be personal to himself, and shall not be transferable or transmissible by his own act or by operation of law.

ADMISSION.

C 13. All applications for membership as Member, Associate or Junior shall be presented to the Council, which shall consider and act upon each application, assigning each approved applicant to the classification to which, in the judgment of the Council, he is entitled. The name of each candidate thus approved by the Council shall, unless objection is made by the applicant, be submitted to the voting membership for election by means of a letter ballot.

C 14. Associates or Juniors desiring to change their grade of membership shall make application to the Council in the same manner as is required in the case of a new applicant.

C 15. Election to membership shall be by a sealed letter ballot as the By-Laws shall provide. Adverse votes to the number of four per cent. of the votes cast shall be required to defeat the election of an applicant.

C 16. Each person elected shall subscribe to this Constitution, and shall pay the initiation fee before he can be entitled to the rights and privileges of membership. If such person does not comply with these requirements within six months after notice of his election he will be deemed to have declined election. The Council may, thereupon, declare his election void.

INITIATION FEES AND DUES.

C 17. The initiation fee for membership shall be as follows:

For Members and Associates, five dollars.

For Juniors, five dollars.

A Junior on promotion to any other grade of membership shall pay an additional fee of five dollars.

The annual dues for membership shall be as follows:

For Members and Associates, ten dollars.

For Juniors, five dollars, for the first six years of their membership, and thereafter the same as for a Member or Associate.

SUSPENSIONS AND EXPULSIONS.

C 18. Any Member, Associate or Junior who shall leave his annual dues unpaid for two years shall, at the discretion of the Council, have his name stricken from the roll of membership and shall cease to have any further rights of membership.

C 19. The Council may refuse to receive the dues of any Member, Associate or Junior who shall have been adjudged by the Council to have violated the Constitution or By-Laws of the Society, or who, in the opinion of the Council, expressed by a two-thirds vote of the entire Council, shall have been guilty of conduct rendering him unfit to continue in its membership; and the Council may expel such person and remove his name from the list of members.

THE COUNCIL.

C 20. The affairs of the Society shall be managed by a Board of Directors chosen from among its Members and Associates, which shall be styled "The Council." The Council shall consist of the President of the Society, who shall be presiding officer; the two Vice-Presidents, Treasurer and nine Members or Associates. Seven Members of the Council shall constitute a quorum for the transaction of business. The Secretary may take part in the deliberations of the Council, but shall not have a vote therein.

C 21. The Council thus constituted shall regulate its own proceedings and shall be the legal Trustee of the Society. All gifts or bequests not designated for a specific purpose shall be invested by the Council, and only the income therefrom may be used for current expenses.

C 22. Should a vacancy occur in the Council, or in any elective office except the presidency, through death, resignation or other cause, the Council may elect a Member or Associate to fill the vacancy until the next annual election.

C 23. The Council shall present at the Annual Meeting of the Society a report, verified by the President or Treasurer or by a majority of the members of the Council, showing the whole amount of real and personal property owned by the Society, where located,

and where and how invested, and the amount and nature of the property acquired during the year immediately preceding the date of the report, and the manner of the acquisition; the amount applied, appropriated or expended during the year immediately preceding such date, and the purposes, objects or persons to or for which such applications, appropriations or expenditures have been made; also the names and places of residence of the persons who have been admitted to membership in the Society during the last year, which report shall be filed with the records of the Society, and an abstract thereof shall be entered in the minutes of the proceedings of the Annual Meeting.

C 24. An act of the Council which shall have received the expressed or the implied sanction of the membership at the next subsequent meeting of the Society shall be deemed to be the act of the Society, and shall not afterward be impeached by any member.

C 25. The Council may, by a two-thirds vote of the members present, declare any elective office vacant, on the failure of its incumbent for one year, from inability or otherwise, to attend the Council meetings, or to perform the duties of his office, and shall thereupon appoint a Member or Associate to fill the vacancy until the next Annual Meeting. The said appointment shall not render the appointee ineligible to election to any office.

OFFICERS.

C 26. At each Annual Meeting there shall be elected from among the Members and Associates:

A President to hold office for one year.

Two Vice-Presidents, one to hold office for one year and one to hold office for two years. After the first year one Vice-President to be elected annually for a term of two years.

A Treasurer to hold office for one year.

Nine Members or Associates shall be elected to the Council at the first Annual Meeting, three to hold office for one year, three to hold office for two years, and three to hold office for three years, and at each subsequent Annual Meeting three Members or Associates shall be elected, each to serve three years.

C 27. The election of officers shall be by ballot, as the By-Laws shall provide.

C 28. The term of all elective officers shall begin on the adjournment of the Annual Meeting of the Society. Officers shall continue in their respective offices until their successors have been installed.

C 29. A President or Vice-President shall not be eligible for immediate re-election to the same office at the expiration of the term for which he was elected.

C 30. The Council, at its first meeting after the Annual Meeting of the Society, shall appoint a Member or Associate to serve as Secretary of the Society subject to the pleasure of the Council. The Secretary shall receive a salary which shall be fixed by the Council at the time of his appointment.

C 31. The President, Secretary and Treasurer shall perform the duties legally or customarily attaching to their respective offices under the laws of the State of New York, and such other duties as may be required of them by the Council.

C 32. A vacancy in the office of President shall be filled by the Vice-President who is senior by age.

MEETINGS.

C 33. The Society shall hold its Annual Meeting in New York City on the Monday preceding the first Tuesday in December, and such other meetings shall be held at such times and places as the Council may appoint. Twenty-five Members and Associates shall constitute a quorum for the transaction of business.

C 34. Special meetings of the Society may be called at any time at the discretion of the Council, or shall be called by the President upon the written request of twenty-five members entitled to vote.

C 35. Any appropriation recommended by the Society at a meeting shall not take effect until it has been approved by the Council.

C 36. Every question which shall come before a meeting of the Society or of the Council or a Committee shall be decided by a majority of the votes cast, unless otherwise provided in this Constitution or the By-Laws, or the Laws of the State of New York. The Council may order the submission of any question to the membership for discussion by letter ballot. Any meeting of the Society at which a quorum is present may order the submission of any question to the membership for discussion by letter ballot.

STANDING COMMITTEES.

C 37. The standing committees of the Society shall be:

Finance Committee. Publication Committee.

Membership Committee.

The members of these Committees shall be appointed by the President from members of the Council who are not officers of the Society.

TRANSACTIONS.

C 38. The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings. Matters. relating to politics, religion or purely to trade shall not be discussed at a meeting of the Society nor be included in the Transactions.

C 39. The Society shall not approve any engineering or commercial enterprise, nor allow its imprint or name to be used in any commercial work or business. No member shall describe himself in connection with the Society in any advertisement other than as a Member, Associate Member or Junior Member.

AMENDMENTS.

C 40. At Annual Meetings of the Society any Member or Associate may propose in writing for discussion an amendment to this Constitution. Such proposed amendment shall not be voted on at that meeting, but shall be open for discussion and such modification as may be accepted by the proposer. The proposed amendment shall be mailed by the Secretary to each Member and Associate at the time the notice of the next Annual Meeting issues, and shall be voted upon at said meeting.

C 41. Such By-Laws shall be enacted as will conform with this Constitution and the laws of the State of New York and as are required to conduct the business of the Society.

BY-LAWS.

CANDIDATES FOR MEMBERSHIP.

B 1. A candidate for admission to the Society as a Member or as an Associate must make application on a form approved by the Council, upon which he shall write a statement giving a complete account of his qualifications and engineering experience, and an agreement that he will, if elected, conform to the Constitution, By-Laws and Rules of the Society. He must refer to at least four Members or Associates to whom he is personally known.

B 2. Applications for membership from Refrigerating Engineers who are not residents in the United States or Canada, and

who may be so situated as not to be personally known to four Members or Associates of the Society, as required in the foregoing paragraph, may be recommended for ballot by four members of the Council, after sufficient evidence has been secured to show that in their opinion the applicant is worthy of admission to the grade which he seeks.

B 3. A candidate for admission to the Society as a Junior must make application in the same manner as provided for Members or Associates, except that he must refer to not less than three Members or Associates to whom he is personally known.

B 4. The references for each candidate for admission to the Society shall be requested to make a confidential communication to the Membership Committee, setting forth in detail such information, personally known to the referee, as shall enable the Council to arrive at a proper estimate of the eligibility of the candidate for admission to the Society.

ELECTION OF MEMBERS.

B 5. The Secretary shall mail to each member entitled to vote, at least thirty days in advance of any meeting, a ballot stating the names and the respective grades of the candidates for membership in the Society which have been approved by the Council, and the time of the closure of voting. The voter shall prepare his ballot by crossing out the names of candidates rejected by him, and shall enclose said ballot in a sealed blank ballot envelope, which he shall then enclose in a second sealed outer envelope, on which he shall, for identification, write his name in ink. The ballot thus prepared and enclosed shall be mailed or delivered unopened to the Tellers of Election. The Secretary shall certify to the competency and the signatures of all voters. On the closure of voting, the Tellers of Election shall first open and destroy the outer envelopes, and shall then canvass the ballots, and certify the result to the meeting of the Society.

B 6. The Tellers of Election shall not receive any ballot after the stated time of the closure of voting. A ballot without the endorsement of the voter written in ink on the outer envelope is defective, and shall be rejected by the Tellers of Election.

B 7. The names of those persons elected to membership, with their respective grades, shall be embodied in a written report, signed by the Tellers, and presented to the next meeting of the Society. The President shall then declare them duly elected to membership in the Society. The Tellers may, through the Secretary, in advance

of any meeting, advise each candidate of the result of the canvass of the votes in his case. The names of applicants who are not elected shall neither be announced nor recorded in the Transactions.

B 8. The endorsers of an applicant who has not been elected may, with his consent, present to the Council a written request for a re-submission of his name to ballot. The Council may, in its discretion, by a three-fourths vote of the members present, order the name of the applicant placed on the next ballot for members.

B 9. Each person elected to membership must subscribe to the Constitution, By-Laws and Rules of the Society, and pay the initiation fee before he can receive a certificate of membership in the Society.

ELECTION OF OFFICERS.

B 10. The Secretary shall mail to each member entitled to vote, at least thirty days before the Annual Meeting, the names of the candidates for office proposed for election by the Nominating Committees.

B 11. The names of the candidates proposed by the Nominating Committee or Committees, and the respective offices for which they are candidates, shall be printed in separate lists on the same ballot sheet, each list of candidates to be printed under the names of the members of the particular committee which proposed it.

B 12. The name of any candidate on the ballot may be erased, and the name of any person qualified to hold the office written in its stead. The ballot must be voted and canvassed in the same manner as for the election of members.

B 13. In case of a tie in the vote for any officer, the President, or, in his absence, the Presiding Officer, shall cast the deciding vote.

B 14. A ballot which contains more names on it than there are officers to be elected is thereby defective, and shall be rejected by the Tellers.

FEES AND DUES.

B 15. The initiation fee and annual dues of the first year shall be due and payable on notice of election to membership. Thereafter the annual dues shall be due and payable on the first day of December in each year.

B 16. A member in arrears for one year shall not be entitled to vote until such arrears have been paid. Should the right to vote be questioned, the books of the Society shall be conclusive evidence.

B 17. The Secretary shall present to the Council the name of any Member, Associate or Junior in arrears for more than one year.

A person dropped from the rolls for non-payment of dues may, at the discretion of the Council, be restored to the privileges of membership, upon payment of all arrears.

FINANCIAL ADMINISTRATION.

B 18. The Council at its first meeting in each fiscal year shall consider the recommendations of the Finance Committee concerning the expenditures necessary for the work of the Society during that year. The apportioning of the work of the Society among the various standing and other committees shall be on a basis approved by the Council and in harmony with the Constitution and By-Laws. The appropriations approved by the Council, or so much thereof as may be required for the work of the Society, shall be expended by the various Committees of the Society, and all bills against the Society for such expenditure shall be certified by the Committee making the expenditure and shall then be sent to the Finance Committee for audit. Money shall not be paid out by any officer or employee of the Society except upon bills duly audited by the Committee, or by resolution of the Council.

FINANCE COMMITTEE.

B 19. The Finance Committee shall consist of three members of the Council appointed for a term of one year. The Committee shall, under the direction of the Council, have supervision of the financial affairs of the Society, including the books of account.

PROGRAM COMMITTEE.

B 20. The President shall appoint a Committee from the members of the Council who shall procure professional papers, to pass upon their suitability for presentation, and to suggest topical subjects for discussion at the meetings. The Committee may refer any paper presented to the Society to a person or persons, especially qualified by theoretical knowledge or practical experience, for their suggestions or opinions as to the suitability of the paper for presentation. Papers from non-members shall not be accepted except by unanimous vote of the Committee. The Committee shall arrange the program of each meeting of the Society, and shall have general charge of the entertainments to be provided for the members and guests at each meeting. It shall prohibit the distribution or exhibition at the headquarters or at the meeting places of the Society of all advertising circulars, pamphlets or samples of commercial apparatus or machinery. At the end of each fiscal year the Committee

shall deliver to the Secretary for presentation to the Council a detailed report of its work.

PUBLICATION COMMITTEE.

B 21. The Publication Committee shall consist of three members of the Council appointed for a term of one year. The Committee shall review all papers and discussions which have been presented at the meetings, and shall decide what papers or discussions, or parts of the same, shall be printed. At the end of each fiscal year the Committee shall deliver to the Secretary for presentation to the Council a detailed report of its work.

MEMBERSHIP COMMITTEE.

B 22. The Membership Committee shall consist of three members of the Council appointed for a term of one year. It shall be the duty of this Committee:

To receive and scrutinize all applications for membership to the Society.

To seek further information as to the qualifications of any applicant whose evidence of eligibility is not clear to the Committee.

To report to each session of the Council the names of all applicants under consideration, together with the action of the Committee on each.

The Committee shall at once destroy all correspondence in relation to each applicant when his name has been placed on the ballot by order of the Council, or upon the withdrawal of the application.

NOMINATING COMMITTEES.

B 23. A Nominating Committee of five Members or Associates shall be appointed by the President within three months after he assumes office. It shall be the duty of this Committee to send to the Secretary on or before October 1st the names of consenting nominees for the elective offices next falling vacant under the Constitution. Upon the request of any Member or Associate, the Secretary shall furnish to the applicant the names of such nominees.

B 24. A special Nominating Committee, if organized, shall, on or before October 20th, present to the Secretary the names of the candidates nominated by it for the elective offices next falling vacant under the Constitution, together with the written consent of each.

TELLERS.

B 25. The Presiding Officer shall, at the first session of the Annual Meeting, appoint three Tellers of Election of Officers, whose duties shall be to canvass the votes cast, and report the result to the meeting. Their term of office shall terminate when their report of the canvass is presented to the meeting.

B 26. The President within one month after assuming office shall appoint three Tellers of Election of Members to serve for one year, whose duties shall be to canvass the votes cast for members during the year, and to certify the same to the President. They shall notify candidates through the Secretary of the result of such election.

B 27. The President shall appoint three Tellers to canvass any letter ballots which shall be ordered by the Council or by the Society.

SECRETARY.

B 28. The Secretary of the Society shall be the Secretary to the Council.

The Secretary shall, under the supervision of the Finance Committee, have charge of the Books of Account of the Society.

He shall make and collect all bills against members or others.

All bills against the Society shall be delivered to the Secretary. He shall immediately enter them in the Books of Account, and shall immediately deposit such funds as he receives to the credit of the Society in a bank to be designated by the Council.

TREASURER.

B 29. The Treasurer shall make payments only on the audit of the Finance Committee, or upon the direction of the Council, by resolution of that body. He shall furnish a bond for the faithful performance of his duties to such amount as the Council may require, such bond to be procured from an incorporated Guarantee Company, at the expense of the Society.

TITLES, EMBLEMS, CERTIFICATES.

B 30. Each Member, Associate and Junior shall, subject to such rules as the Council may establish, be entitled on request to a certificate of membership, signed by the President and Secretary of the Society. Every such certificate shall remain the property of the Society, and shall be returned to it on demand of the Council.

B 31. Each proxy authorizing a person to vote for an absent member shall be signed by such absent member, with an attesting

witness, and be submitted to the Secretary for verification of the member's right to vote at the meeting at which the right is to be exercised.

B 32. The emblem of each grade of membership approved by the Council shall be worn by those only who belong to that grade. The official stationery shall be used only by Officers and Committees of the Society for official business.

B 33. The abbreviations of the titles of the various grades of membership approved by the Society are as follows:

For Members—Mem. Am. Soc. R. E.
For Associates—Assoc. Am. Soc. R. E.
For Juniors—Jun. Am. Soc. R. E.

ORDER OF BUSINESS.

B 34. Roll Call.
Reading of minutes of previous meeting.
Report of Tellers of Election of Membership.
Report of the Council.
Unfinished business.
New business.
Report of Tellers of Election of Officers.
Reading of papers and discussions.

PARLIAMENTARY RULES.

B 35. In all questions arising at any meeting involving parliamentary rules not provided for in these By-Laws, "Cushing's Manual" shall be the governing authority.

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PROCEEDINGS

OF THE

THIRD ANNUAL MEETING

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

New York, N. Y., December 2 and 3, 1907.

The third annual meeting of The American Society of Refrigerating Engineers was held in the Engineering Societies Building, No. 29 West Thirty-ninth street, New York, N. Y., on Monday and Tuesday, December 2 and 3, 1907. Four sessions were held, Monday morning, afternoon and evening, and Tuesday morning. Owing to the unavoidable absence of President D. S. Jacobus the sessions were presided over by Vice-Presidents John E. Starr and James Wills. Vice-President Starr called the sessions of Monday morning and afternoon and Tuesday morning to order, while Vice-President Wills presided over Monday evening's session.

First Session, Monday Morning, December 2.

The first session of the meeting was called to order by Vice-President John E. Starr at about 10 A. M., and he announced that President D. S. Jacobus was unable to attend the meeting, he being in California on some important engineering work that required his personal attention, and that the sessions would be presided over by the Vice-Presidents.

The following letter from President Jacobus was read at this point:

HOTEL REDONDO, REDONDO BEACH, Cal., November 17th, 1907.

Dear Mr. Ross:

I have waited until the last moment before sending you word that I will not be able to attend the coming meeting of The American Society of Refrigerating Engineers. I hoped that it would be possible for me to be back in time, or to make a special trip East for the meeting and return to work here, as I did last year when at Denver, but circumstances are such that it will be impossible for me to do this. Kindly tender my regrets to those at the meet-

ing, and say that I cannot express my great disappointment in not being able to be with them.

Enclosed you will find a copy of an address which I prepared for presentation at the meeting. Will you read this for me and extend to all my best greetings?

With earnest wishes for the continued prosperity of the Society, I am,

Yours very truly,

D. S. JACOBUS.

To Mr. W. H. Ross, Secretary,
The American Society of Refrigerating Engineers,
No. 258 Broadway, New York City.

The roll call of members was now heard and the following were found to be present:

Block, Louis.....New York, N. Y.
Borgstedt, H.....New York, N. Y.
Brownell, C. H.,
Washington Court House, Ohio
Burhorn, Edwin....New York, N. Y.
Cary, Albert A.....New York, N. Y.
Cole, Harold W....New York, N. Y.
Cooper, Madison...Watertown, N. Y.
Daly, B. F.....New York, N. Y.
Ely, James.....New York, N. Y.
Greene, Van Rensselaer H.,
New York, N. Y.
Gueth, Oswald.....Brooklyn, N. Y.
Haire, David E.....Philadelphia, Pa.
Jenks, L. Howard...New York, N. Y.
Johnson, Albert.....St. Louis, Mo.
Manns, W. H.....Waynesboro, Pa.
Matthews, F. E.....Hartford, Conn.
Parsons, W. Everett,
New York, N. Y.
Penney, Edgar.....Newburgh, N. Y.
Roelker, H. B.....New York, N. Y.
Ross, W. H.....New York, N. Y.
Rowe, S. J.....New York, N. Y.
Ruddick, J. A.....Ottawa, Canada
Sargent, Allston....New York, N. Y.
Shipley, Thomas.....York, Pa.
Shipley, William S..New York, N. Y.
Shipman, R. L.....Ithaca, N. Y.
Smart, J. M.....New York, N. Y.
Sparks, John C.....New York, N. Y.
Starr, John E.....New York, N. Y.
Strickler, A. B.....York, Pa.
Tinker, H. W.....Boston, Mass.
Vesterdahl, Karl...New York, N. Y.
Vogt, Henry.....Louisville, Ky.
Voorhees, Gardner T.,
New Orleans, La.
Voss, Bernhard.....New York, N. Y.
Wait, John C.....New York, N. Y.
Warner, Irving.....Wilmington, Del.
Wegemann, Karl...New York, N. Y.
Werliin, Louis.....Philadelphia, Pa.
Wills, James.....New York, N. Y.
Winborg, A.....York, Pa.
Wittemann, R. W...New York, N. Y.
Woodcock, W. J.....Brooklyn, N. Y.

The minutes of the second annual meeting were then read and approved. They were as follows:

MINUTES OF THE SECOND ANNUAL MEETING OF THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

The Society held its second annual meeting in the society house of the American Society of Mechanical Engineers, No. 12 West Thirty-first street, New York, N. Y., on Monday and Tuesday, December 3 and 4, 1906. Four sessions were held, Monday morning, afternoon and evening, and Tuesday morning, all being called to order by President W. Everett Parsons.

FIRST SESSION, MONDAY MORNING, DECEMBER 3.

The first session of the meeting was called to order at about 10 A. M., and after forty-four members responded to the roll call, and a quorum being announced, the meeting was declared open for business.

The minutes of the first annual meeting were then read and approved.

The report of the Tellers of Election of Membership was next received. They reported that nine applicants for membership in the grade of Member, ten in the grade of Associate Member, and nine in the grade of Junior Member had been elected to membership. They also reported that one Associate Member had been elected a Member.

The President then declared the successful applicants duly elected to their respective grades and entitled to the rights and privileges of membership, if they had complied with the provisions of the Constitution and By-Laws covering new members.

The roll call of new members was next in order, and eight were found to be present.

The report of the Council was now heard and accepted.

The amendment to the Constitution and the amendment to the By-Laws, introduced at the first annual meeting by J. Shipman Louis, were now taken up for final discussion and action. After some discussion they were unanimously approved.

President Parsons next called for the report of the committee that was appointed at the first annual meeting to visit the test plant of the York Manufacturing Company, at York, Pa., to conduct tests on problems connected with mechanical refrigeration. Vice-President John E. Starr, chairman of the committee, made an informal report, as follows:

"Mr. President, I am sorry to say that this committee will be unable to make a report at this meeting. The causes are twofold. All of the members of the committee were pretty busily engaged this year, but that would not have prevented the investigations at York. It just so happened that it was inconvenient for the York Manufacturing Company to have the experiments conducted early in the year, and later, in October, there were only two of the committee available. The committee also felt that while Mr. Shipley stood by his invitation the shop was so crowded with work that it would be a matter of great inconvenience to the company to take up the subject. The matter was therefore left over."

The committee was continued.

The next order of business was the report of the Tellers of Election of Officers. They reported that Prof. D. S. Jacobus had been elected President; James Wills, Vice-President; Walter C. Reid, Treasurer, and F. W. Pilsbry, J. J. de Kinder and L. Williams, directors.

The President declared the new officers duly elected, and appointed Vice-President John E. Starr and Director Henry Torrance, Jr., a committee to escort President-elect Jacobus to a chair beside him.

President-elect Jacobus thanked the members for the honor, and stated that he would certainly do the very best he could to serve the Society in every way.

The address of President Parsons was now heard.

Following his address, the President read a paper on "A Future for the Ice Manufacturing Industry."

H. B. Roelker then read a paper on "The Allen Dense Air Refrigerating Machine."

The session adjourned at this point for luncheon in the supper room, arranged for by the Program Committee.

SECOND SESSION, MONDAY AFTERNOON, DECEMBER 3.

The meeting was called to order about 1 P. M. The following four papers were presented at this session:

"Experiments with Binary Refrigeration," by Edgar Penney; "Description of a Cold Storage Plant Utilizing Exhaust Steam," by Henry Torrance, Jr.; "Refrigeration of Butter and Cheese," by C. E. Gray, and "Multiple Effect Compressors," by G. T. Voorhees.

A vote of thanks was extended Mr. Gray for his valuable paper.

The topic "How Can Leakage Be Prevented in Cellular Brine Plates?" was discussed at this session.

The session then adjourned.

THIRD SESSION, MONDAY EVENING, DECEMBER 3.

The meeting was called to order a few minutes after 8 P. M. The papers read at this session were: "Insulation," by Junius H. Stone; "The Water Jacketing of Ammonia Compressors," by R. L. Shipman, and "Engineers' Specifications *versus* Contractors' Warranty," by John C. Wait.

Following the reading of the papers, Harry Y. Norwood, Rochester, N. Y., gave an illustrated lecture on "Thermometry and Temperature Regulation." A vote of thanks was tendered Mr. Norwood for his interesting lecture.

Vice-President Starr acted as chairman during part of this session, taking the chair before Mr. Wait began to read his paper.

The session then adjourned.

FOURTH SESSION, TUESDAY MORNING, DECEMBER 4.

The last session of the meeting was called to order shortly after 9 A. M. The following papers were presented:

"Horse Power Per Ton of Refrigeration for Ammonia Compression Machines," by Thomas Shipley; "Data on Water Cooling Towers," by B. Franklin Hart, Jr., and "Oily Waters and Their Treatment," by Albert A. Cary.

Additional topical discussions were taken up at this session. They were as follows:

"What Is the Best Method of Thawing Off Plate Ice?", "Is There Any Better Method of Making Can Ice Than the Usual Plan of Submerging Cans in Brine?", "What Precautions Are Necessary to Safely Test an Old Compression System with Air?", "Experience with Different Forms of Piston Rod Packing" and "Concrete Construction for Ice Tanks."

J. J. de Kinder extended an invitation to those present to visit the new plant of the United Water Improvement Company, Philadelphia, Pa.; H. N. Borgstedt extended an invitation on behalf of the De La Vergne Machine Company, New York, N. Y., to visit its plant, and all present were invited to witness an exhibition of "Thermit" welding by the Goldschmidt Thermit Company during the afternoon at its storeroom, 179 Christopher street.

A unanimous vote of thanks was extended to President Parsons for the able and pleasant way in which he carried out the arduous duties of his office.

The meeting then adjourned.

(Signed) W. H. Ross, Secretary.

The next order of business was the report of the Tellers of Election of Membership. It was as follows:

NEW YORK, N. Y., November 19, 1907.

Dr. D. S. JACOBUS, President,
The American Society of Refrigerating Engineers,
No. 258 Broadway, New York City.

Dear Sir:

The Tellers of Election of Membership met on the morning of November 19 and canvassed the ballots for new members, and have to report that the following have been elected to membership in the grades indicated:

MEMBERS.

Ashton, Walter S.....St. Louis, Mo.
Bishop, Albert C.....Detroit, Mich.
Blethen, Henry.....Seattle, Wash.
Boland, William J.....Chicago, Ill.
Boyer, Francis H..Somerville, Mass.
Dorr, Arthur L.....Boston, Mass.
Goodmanson, Frank A.,
Puerto la Plata, Argentine Republic
Hunter, George C.....Chicago, Ill.
Kilian, Justus.....Seattle, Wash.
Kolischer, Theodore, Philadelphia, Pa.
Moore, Hervey M...Springfield, Mo.
Pownall, Henry D..Cincinnati, Ohio
Tait, Roderick H.....St. Louis, Mo.
Taylor, John R.....Dallas, Tex.
Taylor, Walter A..New Orleans, La.
Thompson, M. W..Greensboro, N. C.
Waite, Nelson J.....Cleveland, Ohio
Walter, Bruce.....Pittsburg, Pa.

ASSOCIATE MEMBERS.

Bonnell, Charles E.....Chicago, Ill.
Briggs, John N.....Coeymans, N. Y.
Collins, J. A.....Petersburg, Va.
Graham, Robert James,
Belleville, Ontario, Canada.
Holzbaur, William J.Kansas City, Mo.
Hoos, William L....Philadelphia, Pa.
Horne, Frank A....New York, N. Y.
Lewis, Eugene W..Jersey City, N. J.
Livezey, John R....Philadelphia, Pa.
Lynch, John H.....New York, N. Y.
Moore, Herbert.....Memphis, Tenn.
Morton, William P.Philadelphia, Pa.
Parsons, Charles H.Springfield, Mass.
Smith, Guy B.....Brooklyn, N. Y.
Stephens, L. H., Jr....Detroit, Mich.
Stevenson, S. P.....Chester, Pa.
Stringer, M. W.....Chicago, Ill.
Whitten, William H..Oakland, Cal.
Wright, George W...Baltimore, Md.

JUNIOR MEMBERS.

Baars, Ernst S. H..Milwaukee, Wis.
Cavnah, Howard E.,
San Francisco, Cal.
Cole, Donald.....Canton, Ohio
Delle, Frank A.....Cashton, Wis.
Dickinson, Raymond N.,
Hartford, Conn.
Hoffman, Carl E....Milwaukee, Wis.
Kremer, Waldemar R.,
Milwaukee, Wis.
McKee, Thomas C.....Chicago, Ill.
Prell, John S....San Francisco, Cal.
Robertson, Gay A.....St. Louis, Mo.

CHANGE OF GRADE OF MEMBERSHIP FROM JUNIOR MEMBER TO MEMBER.

Shipley, William S., New York, N. Y.

CHANGE OF GRADE OF MEMBERSHIP FROM ASSOCIATE MEMBER TO MEMBER.

Markel, Emerich J., New Haven, Conn.

Seventy-two ballots were cast, two of which were void.

Respectfully submitted,

(Signed) H. BORGSTEDT, Chairman, KARL WEGEMANN, F. J. FLOCKE, *Tellers of Election of Membership.*

Vice-President Starr declared the successful applicants for membership duly elected to their respective grades, and requested the Secretary to call the roll of new members. The following responded:

Briggs, J. N.....Coeymans, N. Y.
Horne, Frank A....New York, N. Y.
Hunter, George C.....Chicago, Ill.
Kolischer, Theodore, Philadelphia, Pa.
Lewis, Eugene W..Jersey City, N. J.
Livezey, John R.....Philadelphia, Pa.
Morton, William P..Philadelphia, Pa.
Smith, Guy B.....Brooklyn, N. Y.
Stevenson, S. P.....Chester, Pa.
Waite, Nelson J.....Cleveland, Ohio

The report of the Council was now heard and accepted. It was as follows:

REPORT OF THE COUNCIL OF THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS FOR THE FISCAL YEAR ENDING NOVEMBER 30, 1907.

The Council held two executive sessions during the year, and it respectfully presents herewith a report of the business transacted.

The amount of real and personal property owned by the Society, the property acquired during the year, the amount applied, appropriated or expended, and the purposes and objects for which such expenditures have been made, are contained in the report of the Finance Committee, which follows:

REPORT OF THE FINANCE COMMITTEE.

DR. D. S. JACOBUS, PRESIDENT,
The American Society of Refrigerating Engineers,
No. 258 Broadway, New York, N. Y.

Dear Sir:

Your Finance Committee has to report as follows:

Balance on hand December 1, 1906		$271.75

RECEIPTS.

Initiation fees	$170.00	
Dues	1,310.87	
Caterers	198.00	
Emblems	35.75	
Stenographic reports of 1906 meeting	76.40	
Transactions	25.00	
		$1,816.02
Grand Total		$2,087.77

DISBURSEMENTS.

Caterers	$244.15	
Emblems	15.75	
Furniture	20.75	
Membership certificates	7.25	
Premium on Treasurer's bond	5.00	
Petty cash	127.11	
Printing	322.53	
Rent of A. S. M. E. rooms for 1906 meeting	65.00	
Salaries	550.00	
Stenographic report of 1906 meeting	114.60	
		$1,472.14
Balance on hand		$615.63

Respectfully submitted,

(Signed) EDGAR PENNEY, Chairman.
THOMAS SHIPLEY.
H. B. ROELKER.

At the first meeting of the Council, held on May 2, the following resolution on the death of Mr. Edmond James Smith, of Memphis, Tenn., was introduced and approved, and a copy was ordered sent to the bereaved family:

EDMOND JAMES SMITH.

With deep sorrow The American Society of Refrigerating Engineers takes cognizance of the death on September 17, 1906, of Edmond James Smith, an honored member of this Society, and at the time of his death president of the Memphis Machine Works, Memphis, Tenn.

He was a man of broad and liberal intelligence and indomitable energy, and by these qualities leaves a strongly founded industrial institution, an evidence of his usefulness to mankind as a cherished resident of Memphis and of his native State.

His efforts in mechanical refrigeration were many and varied, a number of plants of his design being successfully operated, which will long remain a monument to his engineering genius.

In their bereavement we tender his family our sincere sympathy, as we do to his business associates and his fellow citizens of Memphis, upon their loss.

The following members have resigned from the membership of the Society during the year:

Mr. A. J. Redway, Associate Member, Cincinnati, Ohio.

Mr. Edward Everett, Associate Member, Pittsburg, Pa.

Mr. Alexander S. Mitchell, Junior Member, Wellington, New Zealand.

The following have been elected to membership in the Society in the three grades during the year:

MEMBERS.

Walter S. Ashton.....St. Louis, Mo.
Albert C. Bishop.....Detroit, Mich.
Henry Blethen.....Seattle, Wash.
William J. Boland.....Chicago, Ill.
Francis H. Boyer..Somerville, Mass.
Arthur L. Dorr.....Boston, Mass.
Frank A. Goodmanson,
Puerto la Plata, Argentine Republic

George C. Hunter.....Chicago, Ill.
Justus Kilian.....Seattle, Wash.
Hervey M. Moore...Springfield, Mo.
Theodore Kolischer, Philadelphia, Pa.
Henry D. Pownall...Cincinnati, Ohio
Roderick H. Tait.....St. Louis, Mo.
John R. Taylor.....Dallas, Tex.
Walter A. Taylor...New Orleans, La.
M. W. Thompson..Greensboro, N. C.
Nelson J. Waite.... Cleveland, Ohio
Bruce Walter.....Pittsburg, Pa.

ASSOCIATE MEMBERS.

Charles E. Bonnell.....Chicago, Ill.
John N. Briggs.....Coeymans, N. Y.
J. A. Collins.....Petersburg, Va.
Robert James Graham, Belleville, Ontario, Canada.
William J. Holzbaur, Kansas City, Mo.
William L. Hoos....Philadelphia, Pa.
Frank A. Horne....New York, N. Y.
Eugene W. Lewis...Jersey City, N. J.
John R. Livezey....Philadelphia, Pa.
John H. Lynch.....New York, N. Y.
Herbert Moore.....Memphis, Tenn.
William P. Morton..Philadelphia, Pa.
Charles H. Parsons, Springfield, Mass.
Guy B. Smith.....Brooklyn, N. Y.
Louis H. Stephens, Jr..Detroit, Mich.
S. Price Stevenson.....Chester, Pa.
M. W. Stringer.....Chicago, Ill.
William M. Whitten....Oakland, Cal.
George W. Wright....Baltimore, Md.

JUNIOR MEMBERS.

Ernst S. H. Baars...Milwaukee, Wis.
Howard Edward Cavnah, San Francisco, Cal.
Donald Cole.....Canton, Ohio
Frank A. Delle.....Cashton, Wis.
Raymond N. Dickinson, Hartford, Conn.
Carl E. Hoffman....Milwaukee, Wis
Waldemar R. Kremer, Milwaukee, Wis.
Thomas C. McKee.....Chicago, Ill.
John S. Prell.....San Francisco, Cal.
Gay A. Robertson.....St. Louis, Mo.

Mr. Emerich J. Markel, formerly an Associate member, has been elected a Member, and Mr. William S. Shipley has been advanced in grade from Junior Member to Member.

Three additional applications for membership are now before the Membership Committee for investigation.

The Council has to report the death of Mr. Frank H. White, of Montreal, Canada, on May 26, a Charter Member of the Society, and hopes that some suitable resolution will be offered at this meeting.

Your President made the following committee appointments on March 29:

MEMBERSHIP COMMITTEE.

L. Howard Jenks, Chairman.

Louis Block. J. J. de Kinder.

FINANCE COMMITTEE.

Edgar Penney, Chairman.

H. B. Roelker. Thomas Shipley.

PUBLICATION COMMITTEE.

Henry Torrance, Jr., Chairman.

L. Howard Jenks. Llewellyn Williams.

PROGRAM COMMITTEE.

James Wills, Chairman.

F. W. Pilsbry. Henry Torrance, Jr.

TELLERS OF ELECTION OF MEMBERSHIP.

Henning N. Borgstedt, Chairman.

Frank J. Flocke. Karl Wegemann.

NOMINATING COMMITTEE.

John E. Starr, Chairman.

John S. De Hart, Jr. Charles Dickerman.
Harry M. Haven. W. Everett Parsons.

William H. Ross was reappointed Secretary of the Society at the first meeting of the Council, with a salary of $400 per year, and he was authorized to spend $200 during the year for the services of a stenographer and incidental expenses.

A free copy of each volume of the Transactions has been ordered sent to the following publications and associations:

Ice and Refrigeration, Chicago, Ill.
Cold Storage and Ice Trade Journal, New York, N. Y.
The Western Brewer, Chicago, Ill.
The Ice Cream Trade Journal, New York, N. Y.
The Brewers' Journal, New York, N. Y.
The American Brewer, New York, N. Y.
The Brewer and Maltster, Chicago, Ill.
The Cold Storage and Ice Association, London, England.
Cold Storage and Ice Trades Review, London, England.
Ice and Cold Storage, London, England.
L'Industrie Frigorifique, Paris, France.
La Glace et les Industries du Froid, Paris, France.
Zeitschrift für die Gesamte Kalte Industrie, Munich, Germany.
Eis- und Kalte-Industrie, Berlin, Germany.
Die Kalte Industrie, Altona, Germany.
L'Avvenire Economico e le Industrie del Freddo, Genoa, Italy.

The exchange of copies of the Transactions has been authorized for the publications of similar societies, subject to the approval of your President.

The Council is having five hundred copies of the 1906 Transactions printed, but owing to many unavoidable delays it has not been able to complete them in time for distribution before this meeting. Members should receive their copies in January, if not at an earlier date.

An effort has been made to have the papers to be read at this meeting printed and distributed among the membership in advance of the meeting, but the Program Committee found it practically impossible to have all of them printed and circulated, owing to the fact that some of the authors found it inconvenient to favor the Society with copies of their papers in time for such action.

The Society has been invited to participate in the International Congress of Refrigerating Industries, to be held in Paris, France, next year. Suitable action will probably be taken at the next meeting of the Council, though views of the membership will be welcomed at this meeting.

Your President has appointed the following as Tellers of Election of Officers: Gardner T. Voorhees, Albert Johnson and A. B. Strickler.

The various committees have met as often during the year as the business before them necessitated and fully performed their duties.

(Signed) WALTER C. REID, Treasurer.

Owing to the absence of President Jacobus the committee that was to conduct tests at the experimental plant of the York Manufacturing Company, at York, Pa., made no report and was continued. Professor R. L. Shipman, of Cornell University, stated that as the test plant of the York Manufacturing Company had been dismantled, he took pleasure in inviting the committee to conduct its tests on the new experimental plant at Sibley College of Cornell University. Professor Shipman was thanked for his invitation, and the matter was left to the committee.

By unanimous vote the Secretary was instructed to send the following telegram of greetings to President Jacobus:

NEW YORK, N. Y., December 2, 1907.

Dr. D. S. JACOBUS,
Redondo Beach, Cal.:

The American Society of Refrigerating Engineers in convention assembled extends greetings to its President and regrets his unavoidable absence.

W. H. ROSS, Secretary.

At this point Vice-President Starr suggested that the Society should take some cognizance of the first meeting of the International Congress of the Refrigerating Industries to be held in Paris, France, in 1908, and stated that a meeting of representatives of various organizations, including The American Society of Refrigerating Engineers, by authority of the Council, was held in Buffalo on November 14, and perfected the organization of an American committee to take charge of the work in this country. He stated that it was desired that all organizations in any way connected with refrigeration should co-operate with the American committee, and if possible assist it in a financial way to enable it to carry on the work expected of the committee, and also pass resolutions asking our National Government to recognize the Congress in an official way and urge the acceptance of the invitation of the French Government to participate in the Congress by sending accredited representatives. He further stated that the Council had power to take the necessary action, but it was felt that an expression of the membership on the subject was desired.

The following resolution was offered and, after discussion, was accepted:

RESOLUTION.

WHEREAS, An International Congress of the Refrigerating Industries, to be held under the auspices of the French Government, has been called to convene in Paris, France, in 1908; and

WHEREAS, The American Society of Refrigerating Engineers and the trade organizations have been invited to co-operate and participate in said Congress; therefore be it

Resolved, That The American Society of Refrigerating Engineers, in con-

vention assembled, recognizing the importance of such International Congress, does hereby heartily endorse the holding of said Congress, and urges the membership of the Society to become members of this Congress, to the end that the maximum benefits from such an International gathering may be secured to our Society; therefore be it further

Resolved, That the Government of the United States, through its proper officials, is hereby requested and urged to give due and adequate recognition of this first International Congress of the Refrigerating Industries, and to accept the invitation of the French Government to participate in its proceedings by sending duly accredited representatives of the United States Government to attend the Congress.

The following motion was introduced by L. Howard Jenks, and after being discussed was accepted:

That this convention recommend to the Council of the Society that an appropriation be made to the American Committee of the International Congress of the Refrigerating Industries, that we may co-operate in the movement to develop the arts and sciences in relation to refrigerating engineering, for which purpose this Society was formed.

The Secretary.—I propose an amendment to paragraph B 24 of the By-Laws for discussion at this the third annual meeting, and for further discussion and final action at the next, the fourth annual meeting.

Paragraph B 24 now reads:

B 24. A Special Nominating Committee, if organized, shall on or before October 20th present to the Secretary the names of the candidates nominated by it for the elective offices next falling vacant under the Constitution, together with the written consent of each.

I would have it read as follows:

B 24. Twenty or more members entitled to vote may constitute themselves a Special Nominating Committee with the same powers as the Annual Nominating Committee. A Special Nominating Committee, if organized, shall, on or before October 20th, present to the Secretary the names of the candidates nominated by it for the elective offices next falling vacant under the Constitution, together with the written consent of each.

When the committee appointed to draft a Constitution and By-Laws made its report, it overlooked the insertion in the By-Laws of a paragraph defining the number of members of a Special Nominating Committee, also its power, and I feel that if this amendment is accepted it will cover this oversight.

I further propose an amendment to the By-Laws by adding a paragraph, to be known as paragraph B 36, covering the manner of amending the By-Laws:

B 36. These By-Laws may be amended in the same manner as amendments are made to the Constitution.

The Tellers of Election of Officers now made their report. It was as follows:

REPORT OF THE TELLERS OF ELECTION OF OFFICERS.

NEW YORK, N. Y., December 2, 1907.

Dr. D. S. JACOBUS, President,
The American Society of Refrigerating Engineers,
No. 258 Broadway, New York, N. Y.

Dear Sir:

Your Tellers of Election of Officers have canvassed the ballots and beg to report the election of the following gentlemen:

President—Edgar Penney.
Vice-President—Karl E. Vesterdahl.
Treasurer—Walter C. Reid.
Directors { Thomas Shipley. John C. Wait. Karl Wegemann.

Respectfully submitted,

(Signed) ALBERT JOHNSON, A. B. STRICKLER, G. T. VOORHEES, } *Tellers of Election of Officers.*

Chairman Starr then appointed Albert Johnson and Harold W. Cole as a committee to escort the President-elect to a chair beside him.

President-elect Penney, in accepting the presidency, stated as follows:

"I appreciate highly the honor imposed on me, and trust, with your co-operation and assistance, that I may be able to fulfill the duties. Now don't be backward in helping all you can as opportunity presents itself."

Chairman Starr now read President Jacobus's address. It appears in these Transactions as one of the papers of the meeting.

The session then adjourned for luncheon in the building, arranged for by the Program Committee.

Second Session, Monday Afternoon, December 2.

The meeting was called to order at about 1:30 P. M. The following three papers were presented at this session:

"Cold Storage by Means of Ice," by Madison Cooper; "Recent Investigations in the Handling of Perishable Products for Transportation by the United States Department of Agriculture," by S. J. Dennis; "The Automatic Refrigerating Machine," by Van Rensselaer H. Greene.

Mr. Dennis prefaced his paper with the following remarks:

"Before proceeding to read my paper I should perhaps add a word of explanation as to the reason why I have limited myself to rather general statements, and that is that this same matter is in process of publication by

the United States Department of Agriculture, and it is not the policy of the department to issue for publication matter which is about to be published."

A vote of thanks was extended Mr. Dennis for his able and interesting paper.

The participants in the discussion on the three papers presented at this session were as follows:

On Mr. Cooper's paper.—Allston Sargent, Irving Warner, Edgar Penney, Gardner T. Voorhees, Thomas Shipley, F. E. Matthews, Louis Block, R. L. Shipman, John A. Ruddick, Mr. Cooper and Chairman Starr.

On Mr. Dennis's paper.—Louis Block, W. Everett Parsons, John A. Ruddick, H. D. Stratton, C. H. Brownell, Gardner T. Voorhees, F. E. Matthews, H. W. Tinker, W. H. Ross, Mr. Dennis and Chairman Starr.

On Mr. Greene's paper.—Louis Block, Thomas Shipley, Edgar Penney, F. E. Matthews, L. Howard Jenks, Henry Vogt, W. Everett Parsons, Eugene W. Lewis, H. N. Borgstedt, Theodore Kolischer, Mr. Greene and Chairman Starr.

The session then adjourned.

Third Session, Monday Evening, December 2.

The meeting was called to order shortly after 8 P. M.

The following telegram from President Jacobus was read:

REDONDO, Cal., December 2, 1907.

Mr. JOHN E. STARR, Chairman,
The American Society of Refrigerating Engineers,
No. 29 West Thirty-ninth street,
New York, N. Y.

Convey to the members my deep regret in not being able to be present. This is indeed the greatest of disappointments, and I certainly would have attended had it been possible. I will be with you in spirit, and wish the Society a most successful meeting. D. S. JACOBUS.

The reading and discussion of papers was now taken up. The papers read at this session were:

"Experiences in the Manufacture of Plate Ice," by Irving Warner; "Fireproof Cold Storage Warehouse Construction," by John E. Starr; "The Best Method of Detecting Impurities in Ammonia in Refrigerating Plants," by John C. Sparks.

The following entered into the discussion on the three papers read at this session:

On Mr. Warner's paper.—Thomas Shipley, Louis Block, Karl Wegemann, Albert A. Cary, John E. Starr, Abram Day, H. D. Stratton, Edgar Penney, John A. Ruddick, Karl E. Vesterdahl, Guy

B. Smith, Gardner T. Voorhees, John C. Sparks, Mr. Warner and Chairman Wills.

On Mr. Starr's paper.—F. E. Matthews, Irving Warner, John C. Sparks and Mr. Starr.

On Mr. Sparks's paper.—Albert A. Cary, Gardner T. Voorhees, Guy B. Smith, Thomas Shipley, R. L. Shipman, Albert Johnson, H. Dannenbaum, John E. Starr, Henry Vogt, Mr. Sparks and Chairman Wills.

The session then adjourned.

Fourth Session, Tuesday Morning, December 8.

The last session of the meeting was called to order shortly after 9 A. M. The papers presented at this session were as follows:

"Comparison of Bids for Ice-Making and Refrigerating Machinery," by Thomas Shipley; "The Work of the United States Geological Survey in Its Relation to Refrigeration," by R. B. Dole; "Advantages of the Wet Compression System," by Carl W. Vollmann; "Heat Transfer in Coolers and Condensers of the Double-Pipe Type," by R. L. Shipman.

A vote of thanks was extended to Mr. Dole for his valuable paper, and in responding Mr. Dole said:

"I thank you in the name of the Geological Survey and the other members of the branch, who have worked, probably all of them, harder than I to collect this information. I should like to add something that I forgot to say, namely, that these water-supply papers, written in popular style, are printed for practical use, and a certain percentage of each edition is set aside for free distribution. Copies can be obtained by application to the Director of the Geological Survey. Some of them are now out of stock, but those that are marked out of stock for free distribution can generally be obtained from the Superintendent of Public Documents at Washington by the payment of 5 to 10 cents, covering the actual cost of printing."

Those that took part in the discussions on the four papers read at this session were:

On Mr. Shipley's paper.—Louis Block, Irving Warner, Van Rensselaer H. Greene, Gardner T. Voorhees, Theodore Kolischer, W. Everett Parsons, Mr. Shipley and Chairman Starr.

On Mr. Dole's paper.—S. P. Stevenson and Mr. Dole.

On Mr. Vollmann's paper.—Thomas Shipley and R. L. Shipman.

On Mr. Shipman's paper.—Louis Block and Mr. Shipman.

The topical discussion, "The Standardizing of Measuring Instruments," also received the attention of this session, and the following participated: James Ely, William H. Bower, H. D. Stratton,

H. Dannenbaum, R. L. Shipman, W. Everett Parsons, Gardner T. Voorhees and Chairman Starr.

A vote of thanks was extended to Vice-President Starr for the very efficient and very pleasing manner in which he occupied the chair in the absence of President Jacobus.

The meeting then adjourned.

MEMBERS AND GUESTS ATTENDING MEETING.

Alexander, W. J., Philadelphia, Pa.
Andrews, J. G., New York, N. Y.
Armagnac, A. S., New York, N. Y.
Austin, A. O., New Rochelle, N. Y.
Bates, Guy, New York, N. Y.
Bernhard, H. T., New York, N. Y.
Bilyea, C. T., New York, N. Y.
Block, Louis, New York, N. Y.
Borgstedt, H., New York, N. Y.
Bower, W. H., Philadelphia, Pa.
Bowers, James, Wilmington, Del.
Briggs, J. N., Coeymans, N. Y.
Brownell, C. H.,
Washington Court House, Ohio.
Burhorn, Edwin, New York, N. Y.
Carpenter, C. A., New York, N. Y.
Cary, Albert A., New York, N. Y.
Cary, C. R., Philadelphia, Pa.
Cole, Harold W., New York, N. Y.
Cooper, Madison, Watertown, N. Y.
Daly, B. F., New York, N. Y.
Dannenbaum, H., Philadelphia, Pa.
Day, Abram, Bloomfield, N. J.
Dean, H. Alexander, New York, N. Y.
Dennis, S. J., Washington, D. C.
Dettmar, E., New York, N. Y.
Dole, R. B., Washington, D. C.
Ely, James, New York, N. Y.
Fairbanks, F. L., Boston, Mass.
Farish, J. B., New York, N. Y.
Ferguson, W. W., New York, N. Y.
Fisher, H. R., Philadelphia, Pa.
Frantz, S. R., Waynesboro, Pa.
Gilbreth, Frank B., New York, N. Y.
Gillispie, J. M., Philadelphia, Pa.
Golden, Albert J., Philadelphia, Pa.
Greene, Van Rensselaer H.,
New York, N. Y.
Gueth, Oswald, Brooklyn, N. Y.
Haire, David E., Philadelphia, Pa.
Havenstrite, Charles D.,
New York, N. Y.
Hexamer, W. E., Philadelphia, Pa.
Hill, George F., New York, N. Y.
Hodges, H. F., Philadelphia, Pa.
Holden, D. L., New York, N. Y
Horne, Frank A., New York, N. Y.
Howe, Arthur E., New York, N. Y.
Hoyt, B. S. John, New York, N. Y.
Hunter, George C., Chicago, Ill.
James, Thomas M., New York, N. Y.
Jamison, J. V., Jr., Hagerstown, Md.
Jenks, L. Howard, New York, N. Y.
Johnson, Albert, St. Louis, Mo.
Kehoe, Robert P., New York, N. Y.
Knight, George W., Newark, N. J.
Koenig, Adolph G., New York, N. Y.
Kolischer, Theodore, Philadelphia, Pa.
Laiman, Theodore, Hartford, Conn.
La Vin, J. C., New York, N. Y.
Lewis, Eugene W., Jersey City, N. J.
Livezey, John R., Philadelphia, Pa.
Manns, W. H., Waynesboro, Pa.
Marshall, A. T., Hartford, Conn.
Matthews, F. E., Hartford, Conn.
Mayer, C. G., West Hoboken, N. J.
Mayer, F. W., Jersey City, N. J.
Meehan, John A. New York, N. Y.
Morris, G. Willard, New York, N. Y.
Morton, William P., Philadelphia, Pa.
Newham, H. S., New York, N. Y.
Nulsen, Herbert S., New York, N. Y.
Parsons, W. Everett, New York, N. Y.
Penney, Edgar, Newburgh, N. Y.
Phillips, Louis A., New York, N. Y.
Rautensbauch, Walter,
New York, N. Y.
Reitze, George, New York, N. Y.
Riley, W. H., Wilmington, Del.
Roberts, L. C., Hartford, Conn.

MEMBERS AND GUESTS ATTENDING MEETING—Continued.

Robertson, G. A., St. Louis, Mo.
Robinson, F. G., York, Pa.
Roelker, H. B., New York, N. Y.
Ross, W. H., New York, N. Y.
Rowe, S. J., New York, N. Y.
Ruddick, J. A., Ottawa, Canada.
Sargent, Allston, New York, N. Y.
Schantz, H. W., Buffalo, N. Y.
Serdobin, P. M., New York, N. Y.
Shipley, Thomas, York, Pa.
Shipley, William S., New York, N. Y.
Shipman, R. L., Ithaca, N. Y.
Smart, J. M., New York, N. Y.
Smith, Guy B., Brooklyn, N. Y.
Sparks, John C., New York, N. Y.
Starr, John E., New York, N. Y.
Stevenson, S. P., Chester, Pa.
Stoddard, George H., Boston, Mass.
Stow, Charles F., Philadelphia, Pa.
Stratton, Harrison D., Philadelphia, Pa.
Strickler, A. B., York, Pa.
Suttin, W. S., New York, N. Y.
Tinker, H. W., Boston, Mass.
Vesterdahl, Karl, New York, N. Y.
Vogt, Henry, Louisville, Ky.
Voorhees, Gardner T., New Orleans, La.
Voss, Bernhard, New York, N. Y.
Wait, John C., New York, N. Y.
Waite, Nelson J., Cleveland, Ohio.
Warner, Irving, Wilmington, Del.
Wegemann, Karl, New York, N. Y.
Werliin, Godwin, Wilmington, Del.
Werliin, Louis, Philadelphia, Pa.
Whitall, W. Van R., New York, N. Y.
Wight, Frank C., New York, N. Y.
Williams, E. T., New York, N. Y.
Wills, James, New York, N. Y.
Winborg, A., York, Pa.
Wittemann, R. W., New York, N. Y.
Woodcock, W. J., Brooklyn, N. Y.

THE BANQUET.

The banquet was held at 7 o'clock on the evening of the second day of the meeting at the Hotel Victoria, where an excellent menu was served. Nearly seventy-five members and guests enjoyed the occasion.

Vice-President John E. Starr acted as toastmaster in his usual entertaining manner, and the speakers of the evening kept things merry.

President Penney was the first speaker of the evening, and in his remarks stated that much was expected from the younger members, and he especially appealed to them for co-operation during his term of office. He also took the minds of those present back to olden times and told of the struggles to develop the science of refrigeration, and paid a high tribute to the pioneers for the great work they have done.

Following Mr. Penney's address beautiful loving cups were presented to the first three presidents of the Society. Mr. Louis Block presented a cup to the first president of the Society, Mr. John E. Starr, and Vice-President James Wills presented a cup to Mr. W. Everett Parsons, the second president; while Director John C. Wait presented another cup to Dr. D. S. Jacobus, the retiring president. President Penney accepted the cup for Dr. Jacobus, who

was unavoidably detained in California on some highly important engineering problems and was unable to attend the meeting and the banquet.

The Hon. John A. Ruddick, Dairy and Cold Storage Commissioner of Canada, was the next speaker, and stated that while he was a Canadian by birth he had crossed the border into the United States to choose a life's helpmate, and that their first child was, in a way, a living tribute of their reverence for this country, it being born on July 4. Mr. Ruddick told of the importance of refrigeration in the development of the dairy and fruit industries in Canada, and of the great strides that are being made in the development of its natural resources, and further said that he firmly believed that its position among the countries of the new world would in a few years be second to no other.

Mr. Theodore Kolischer, Philadelphia, Pa., was the next speaker, and his witty remarks about the old-time way of selling refrigerating machinery provoked much laughter.

Mr. Thomas Shipley made the next address. He called the attention of the junior members to the important work before them, and stated that it was highly important that they be well grounded in the fundamental principles of the science, and he was glad to see that they were taking so much interest in the Society.

Mr. Louis Block and Mr. W. E. Hexamer spoke at some length on the effect of the prohibition agitation throughout the country on the brewing industry, which is so closely connected with the history and development of mechanical refrigeration, and their remarks were listened to with marked attention. Statistics to show the vast extent of this industry were given and attention called to its importance in the industries of the nation.

Director John C. Wait called the attention of those present to the great success and large membership of the Society, and he proposed that all drink to the health and happiness of the charter members of the Society for the initiative work that they did.

The toastmaster now called on Mr. C. G. Mayer, one of the old-time builders of refrigerating machinery, to tell of his early experiences in the business. Mr. Mayer told of the troubles he had in building and installing three machines in as many cities in Kentucky in 1877, the first installation being a failure and the last two successes; but he found it difficult to convince the purchasers of the last two apparatus that the machinery would do the work required, as the failure of the first installation was known in the other two cities before he arrived to install the machines.

Mr. Gardner T. Voorhees next spoke on what the younger engineers were doing in the field, and paid a high tribute to the pioneers.

Mr. William H. Bower, Mr. Herman Dannenbaum and Mr. Albert Johnson next made some humorous remarks on ammonia.

The benediction was made by President Penney, and he proposed a silent standing toast to the absent members, particularly those in foreign lands.

The following attended the banquet:

Alexander, W. J., Philadelphia, Pa.
Bates, Guy, New York, N. Y.
Bernhard, H. T., New York, N. Y.
Bilyea, C. T., New York, N. Y.
Block, Louis, New York, N. Y.
Bower, William H., Philadelphia, Pa.
Brownell, C. H.,
Washington Court House, Ohio
Burhorn, Edwin, New York, N. Y.
Cary, Albert A., New York, N. Y.
Cole, Harold W., New York, N. Y.
Dannenbaum, H., Philadelphia, Pa.
Ferguson, W. W., New York, N. Y.
Flocke, F. J., New York, N. Y.
Frantz, S. R., Waynesboro, Pa.
Gillispie, J. M., Philadelphia, Pa.
Greene, Van Rensselaer H.,
New York, N. Y.
Haire, D. E., Philadelphia, Pa.
Hexamer, W. E., Philadelphia, Pa.
Jamison, J. V., Jr., Hagerstown, Md.
Jenks, L. Howard, New York, N. Y.
Johnson, Albert, St. Louis, Mo.
Kehoe, Robert P., New York, N. Y.
Knight, George W., Newark, N. J.
Kolischer, Theodore, Philadelphia, Pa.
La Vin, J. C., New York, N. Y.
Lewis, E. W., Jersey City, N. J.
Livezey, John R., Philadelphia, Pa.
Manns, W. H., Waynesboro, Pa.
Matthews, F. E., Hartford, Conn.
Mayer, C. G., West Hoboken, N. J.
Morton, W. P., Philadelphia, Pa.
Newham, H. S., New York, N. Y.
Nulsen, Herbert S., New York, N. Y.
Parsons, W. Everett,
New York, N. Y.
Penney, Edgar, Newburgh, N. Y.
Phillips, L. A., New York, N. Y.
Rautensbauch, Walter,
New York, N. Y.
Robertson, G. A., St. Louis, Mo.
Roelker, H. B., New York, N. Y.
Ross, W. H., New York, N. Y.
Ruddick, J. A., Ottawa, Canada.
Sargent, Allston, New York, N. Y.
Shipley, Thomas, York, Pa.
Shipley, William S., New York, N. Y.
Shipman, R. L., Ithaca, N. Y.
Smith, Guy B., Brooklyn, N. Y.
Starr, John E., New York, N. Y.
Stevenson, S. P., Chester, Pa.
Stow, Charles F., Philadelphia, Pa.
Strickler, A. B., York, Pa.
Vesterdahl, Karl, New York, N. Y.
Vogt, Henry, Louisville, Ky.
Voorhees, Gardner T.,
New Orleans, La.
Voss, Bernhard, New York, N. Y.
Wait, John C., New York, N. Y.
Waite, N. J., Cleveland, Ohio.
Warner, Irving, Wilmington, Del.
Wegemann, Karl, New York, N. Y.
Werliin, Godwin, Wilmington, Del.
Werliin, Louis, Philadelphia, Pa.
Whitall, W. Van R., New York, N. Y.
Williams, E. T., New York, N. Y.
Wills, James, New York, N. Y.
Winborg, A., York, Pa.
Woodcock, W. J., Brooklyn, N. Y.

PAPERS

OF THE

THIRD ANNUAL MEETING

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

No. 38.

THEORY AND REFRIGERATING ENGINEERING—PRESIDENTIAL ADDRESS.

By D. S. Jacobus, New York, N. Y.

In days not so long ago there was a belief in the minds of many that theory was not necessary to attain success in the engineering field. The old-time engineer was apt to belittle the younger generation with their college-bred ideas, and even to-day there is often a feeling among many practitioners that it is experience rather than book-learning which makes a man valuable in his profession.

It is indeed true that book-learning can be bought and paid for, whereas experience cannot, except in the sense that it is often dearly paid for in the cost of mistakes; but book-learning is not all of theory. To be a good theoretical engineer a man must have theories of his own. The moment a man stops to consider the whys and wherefores of the work in hand—in planning out work combines this and that fact and principle—he is making use of theory which is at his disposal, and this theory is apt to be all the more sound if derived from experience and not gleaned from books.

Often we find a man, who has advanced from some minor position to one where he is given executive power and the handling of men, deride theory and refer to his own career as an example of what can be done by sticking to practice; yet if he were to analyze correctly the reason why he excelled his co-workers, and in the end made himself worth more to his employers, he would find that it was the power he possessed to make use of the information gleaned from his experience, and of being able to combine the same and correlate the facts in such a way that his final conclusions were correct. In other words, without knowing it, he has been applying theory to his work, and he has advanced beyond those around him because of the fact that he possessed the ability to apply properly this theory.

The present generation has seen a change from the old to the new régime in many of the engineering professions; for example, take the case of the gas industry. At a comparatively recent time the art of making illuminating gas was mainly in the hands of men who had been brought up in the profession without any particular

engineering training; but finally younger men entered the field, and, applying their theoretical knowledge, revolutionized the art and led up to the present methods of manufacture.

In none of the sciences is there greater need of a thorough understanding of the theories and underlying principles than in refrigerating engineering. We have great refrigerating engineers, and as time rolls by their names will become even more prominent through being pioneers in the field; but those who will in the future be responsible for the continued dignity of the profession will be the younger men who have been thoroughly grounded in the principles; I say thoroughly grounded, because there is no profession in which a little theory, not well understood, may lead to more disastrous results than in refrigerating engineering.

There is no way of evading the laws of thermo-dynamics, and most engineers are aware of this fact, but there are many ways of making mistakes where the laws of thermo-dynamics do not appear to be broken. Many men with a small and dangerous amount of theory at their disposal will evolve what seems to them to be new schemes for producing refrigeration, and prove to their own satisfaction, by the aid of formulas involving latent heats and other properties of working fluids, that they have devised systems which are superior to any heretofore put forth. They will be certain that all is needed in order that a fortune may be made out of their ideas is simply to build machines to demonstrate the efficiency of their systems, whereas when the schemes are looked into intelligently they are found to be worthless.

It is to check wild schemes of this sort that the refrigerating engineer needs theory, and above all that part of theory which is usually put down as "good common sense." Then again, the refrigerating engineer may have to pass on a system of power production, where, in some parts of the cycle, artificial means are employed to maintain a low temperature. If we could but obtain a low enough condensing temperature in a power plant we could make use of the unlimited amount of heat in the water of the ocean, and in this way produce useful work. Although scientists have told us that in such a case the maintenance of a low temperature for condensation cannot be accomplished without the expenditure of a greater amount of work than that which will be gained, many may still be tempted to evolve power systems which when analyzed amount to this.

The fact that theoretically a much greater amount of refrigeration can be obtained than the heat equivalent of the work required to drive the machine has misled many and has been responsible for

the advancement of impossible schemes. When we come to actual practice the refrigerating effect may be several times as great as the heat equivalent of the applied power, all of which is in line with what is taught us by thermo-dynamics, and yet this is an inducement to many having a small amount of theory at their disposal to endeavor to evolve something which they feel will be in advance of anything now in use in the way of power systems; in fact, in some cases the man with a little theory will prove to his own satisfaction that he has a way of getting around the well-known thermo-dynamic laws.

It is often said that theory follows where practice leads to success; or that, after a thing has been shown to be possible in practice, the theoretical man will show that it is also possible by theory. The old-time engineers will recall many instances where success was attained when so-called scientists predicted failure, thus again showing what appears to be the superiority of practice over theory. Too much cannot be said in recognition of the ability of the old-time engineer. There were no beaten paths, and in many cases no signs, to warn him of danger, and yet he forged ahead, perhaps falling many times by the way, but in the end he made great discoveries. To the perseverance and grit of the old-time engineer we indeed owe much in the development of modern engineering practice. It will always be sturdy characters of the old sort who will make advances. because it takes nerve to institute new departures. All that theory can do for us is to correlate known facts, and mathematics and the kindred sciences can make use of known facts and point out certain lines of development. No new fact can be born of science, and the ambitious are ever seeking the goal of discovery; but science in many cases is a true guardian of our happiness in preventing us from wasting our time seeking what we can never find. We may make mistakes, even when well grounded in certain theories, by having an insufficient knowledge of all the conditions involved. We should not be ashamed of mistakes when honestly working in the best way known in the art, and we should impress this upon the younger engineers. Monuments of success are often built upon foundations of failures, and nearly all great achievements have come through years of endeavor, where many ideas were tried and found wanting. The pioneer in a field may try in many ways and fail to attain the best results, and someone else may step in and, knowing of his experiments and failures, may be able to reach the final goal. The pioneer is often the sower, and the one who comes after him the reaper, and it is only too often that those who reap seem to forget that but for the sowing there would have been no harvest. A noted engineer

once said that "a physician can bury his mistakes, but the mistakes of an engineer always stand out as monuments to his memory." With a saying like this before him a young engineer might feel that he had lost all chances of achieving success after he had made a mistake of a serious character, but it is well to tell him in all confidence that we have all made mistakes, and that it will probably be his fate to do the same should he ever advance far enough to take the initiative and really develop anything which will in the end mark an advance in his profession.

We should impress upon the younger engineers that they cannot advance and become leaders in their profession without hard work on their part. What is laid to the door of genius is in most cases the fruit of hard work and not of idle theory; success is rare, indeed, where there have not been days, nights and years of striving.

I do not wish it to be understood from this that I feel that, in addition to hard work, theory is all that is necessary in gaining success. There is a certain amount of intuition that is necessary to the successful engineer. Without this intuition he can never achieve any great success. I once heard a man speak of another as being "the best educated fool that he knew." Education in the popular sense of the term, where it means simply time spent at some institution of learning, will not make the man. In the higher sense of the term, however, it is education which makes the man, whether this be obtained through books or through the medium of hard knocks in the practical field. It is this education which makes available the laws of nature as embodied in that sound theory needed in advancing refrigerating engineering.

No. 39.

COLD STORAGE BY MEANS OF ICE.

By Madison Cooper, Watertown, N. Y.

(Member of the Society.)

It may be well to state at the beginning of this paper that its mission is to promote the use of ice for cold storage purposes. With this frank confession we may proceed to a discussion of what has been done, what is being done, and what is likely to be done in the cold storage of perishable goods by means of ice.

When ice is mentioned in connection with cold storage the mind naturally turns to the common house refrigerator; or possibly to a butcher's cooler; or, if somewhat posted in the cold storage line, to the overhead system of ice-cold storage; in short, to cooling by circulating the air of the cold storage room in direct contact with ice as the refrigerating medium. There are more ways than one of cooling a cold storage room by means of ice.

The first recognized cold storage system to use ice was originated by Professor Nyce. That gentleman fully understood a fact which some of the subsequent experimenters failed entirely to appreciate—the absolute necessity of separating the refrigerating medium from contact with the air of the cold storage room. He constructed a house with insulated walls, with storage on the ground floor and ice placed above; but there was an absolute separation of the ice chamber from the cold storage room by placing a watertight galvanized iron floor between the ice and the storage room. In some of these houses the entire inner surface of the cold storage room was lined with iron. The cooling of the storage room was accomplished by direct transmission through the iron floor of the ice chamber to the air of the cold storage room. Very creditable temperatures have been obtained in some cases. Moisture coming into the room by opening of doors and that given off by stored goods was taken up by means of chloride of calcium placed either on the watertight floor or suspended near the ceiling. A few of these old houses are still in service. In many respects the Nyce system was superior to the subsequent development in ice cold storage systems, and the insulation was far superior to some of the more modern constructions;

what was lost in quality was more than made up for by increased thickness, sometimes as much as 3 feet being used.

Later systems of cold storage by means of ice, in which the air of the cold storage room was cooled by circulating in direct contact with the air of the cold storage room, were a positive setback to the business instead of an improvement. It might naturally be inferred that lower temperatures would be obtained through more direct contact with the cooling medium, but this advantage was more than lost through failure to appreciate the necessity of good insulation. The systems not only failed to get lower temperatures, but the air of the cold storage room was in most cases more moist, and in some cases more impure than in the Nyce system.

Among the most prominent of these later ice systems may be mentioned the Wickes, which has been very extensively introduced, and is still used largely in the refrigerator car service. For refrigerator cars it is no doubt equally as good as the average end bunker schemes used for this purpose, but for cold storage work it is practically, as generally installed, a failure. The Wickes system has been applied to some large plants, and in some cases resulted in heavy financial losses, not producing even passable results. This system employs end or side icing, and in a fairly large room the circulation was very imperfect, and temperatures were consequently high. Any system or plan of placing the ice in a bunker at one side or one end of the room to be cooled will have this objection.

Many other so-called "systems" came into use about this time, mostly of the overhead ice type, as represented by the Jackson system. The "system" in this case was merely mechanical devices for preventing the waste water, from the melting ice above the room, from causing trouble by dripping or spattering in the room. Certain plates or pieces of metal were provided to protect the girders, and large removable pans of metal backed by wood were hung between the girders to catch all dripping, the air being allowed to circulate down through the joist and flow out around the pan. Flues for the return of warmer air from the room were provided at the ends or sides, extending to near the ceiling of the ice chamber. Various modifications of this system have been largely in use, and are still being installed to a limited extent on account of simplicity and cheapness; but it is needless to say that, where temperatures below 38° to 35° Fahr. are required, they need not be considered. In some of the more recent Jackson plants galvanized tubes filled with crushed ice and salt were added; but this is not at all practicable, because, as the air of the cold storage room is cooled below the temperature

which ice only will give, circulation from the ice chamber ceases and the operation of the overhead ice system is changed from overhead ice to the ice-and-salt tube or direct tankage system.

The Dexter system of cold storage from ice deserves mention as probably being an improvement on any of the systems mentioned. Dexter, as well as Nyce, appreciated the necessity of separating the air of the cold storage rooms from contact with ice as the primary refrigerant. Dexter supports his ice above, and provides a watertight floor between the ice and cold storage room, as did Nyce. He goes still further in providing what is known as the indirect air-circulating system. The air circulates from the ice chamber down through a series of flues or spaces in the interior of the insulation of the walls of the cold storage room. The coldest air direct from the ice circulates down on the inside, or room side, of the wall, and the return air to the ice chamber on the outside, or toward the outside of the building. Practically, this indirect system with an equally good insulation would give as low a temperature as Nyce's system, or lower, as it surrounds the cold storage room with a thin sheet of air at approximately the temperature of the ice chamber. Dexter went still further. He used galvanized iron tubes or tanks, supported from the ceiling of the storage room and fed with chopped ice and salt from the ice chamber. This reduced the temperature, as was expected, but there are many serious difficulties with this scheme. For instance: Dexter's ice floors freeze up and cause much trouble if the temperature of the storage room is reduced much below 32° Fahr. This was later partially overcome by increasing the insulation in the floor between the ice storage room and cold storage room, but the liability of trouble from freezing could not be entirely eliminated. In addition to this, any system of cooling where the ice is placed above is a constant menace to the safety of stored goods below. It is well-nigh impossible to secure a watertight floor under the ice which will be reliable at all times. In addition to this, the storage of ice in an expensive structure like a cold storage house is hardly permissible on account of deterioration to building and insulation. Moisture always condenses on the side walls or ceiling of the ice storage room or ice chamber, and mould and rot soon result.

The direct tankage system, which has been mentioned in describing the Jackson and Dexter systems, is in use independently of any other method of cooling, and has been quite extensively used for certain purposes. This system has many weak features which condemn it for anything like important work or the storage of sensitive goods like butter and eggs. The tanks may be round or of any other

shape, and are usually filled with ice and salt through the floor above. This plan has been used especially in connection with the storage of fish. In most cases thin or flat tanks have been used, and have been termed "freezing walls." These were usually arranged along the sides of the room, and were objectionable on account of only the outer surface being available as cooling surface, the side of tanks near the wall receiving comparatively little or no air circulation. The round tubes are generally about a foot in diameter, and extend from floor to ceiling. However, they may be of any length, and have been installed even as long as 16 feet and as short as 3 or 4 feet. The direct tankage system will produce low temperatures if properly installed and properly handled, but the objections to this system are so many and so important that the system is not to be considered for anything like first-class work. Summed up briefly, the disadvantages of this system are:

First—The tubes are wasteful of space in the room, occupying at least double what the cooling coils of a refrigerating system will occupy.

Second—It is not safe to pile anything beneath or near tubes owing to liability of dripping or spattering, which would damage stored goods.

Third—Icing the tubes through the ceiling of the room causes a wetness which will in time work into and spoil the insulation.

Fourth—Icing the tubes through the ceiling of the room necessitates leaving a considerable space above the storage room, which is wasteful of space, and in a building with two stories of cold storage is practically out of the question.

Fifth—The tubes will not maintain a uniform temperature. Immediately after charging with ice and salt the temperatures will be considerably lower than just before charging.

Sixth—The mud and dirt from the ice collects in the tanks and is likely to cause an odor, which may affect such sensitive goods as butter and eggs.

Seventh—As the frost accumulates on the tubes it is difficult to maintain temperatures in the room. For instance, frost may reach a thickness of 3 inches to 4 inches by midsummer, and it is difficult to hold temperatures on that account. It is practically out of the question to clean the ice from the tubes owing to the difficulty of getting at them, and to the muss and moisture resulting from scattering the frost on the floor.

Eighth—As frost accumulates on the tubes the humidity of the air of the room will become higher.

The writer has had a great deal of experience with the direct tankage system, both as designer and operator of plants equipped with it. He has abandoned the use of this system entirely, and knows from personal experience and the experience of others who are operating plants equipped with it that first-class results cannot be obtained from it, and that deterioration to a building equipped with it is very great.

The Dexter system and the direct tankage or tube system came into use after the introduction of the refrigerating machine. The Jackson system and other systems of direct ice cooling, which circulate the air of the cold storage room in direct contact with the ice, were largely in use about the time the refrigerating machine was introduced. The poor results from these systems and the superior results from refrigerating machines have shown those interested in the storage of perishable goods that ice for cold storage purposes is out of date and a back number. If Professor Nyce's early successes could have been followed up it is more than probable that ice would be more generally used at present, even as compared with refrigerating machines. It is generally admitted by the best posted and most practical engineers with experience with mechanical refrigeration that a refrigerating machine is an undesirable proposition unless at least a fair degree of engineering skill is present to operate and care for it.

The popular idea of cold storage by means of ice usually infers that natural ice is the only ice. It makes no difference whether the ice is made by low temperature weather conditions or by refrigerating machinery. Some very important work is being done where artificial ice is used. For instance, an ice-making plant in the South recently built a cold storage plant and installed the gravity brine system, using ice from the ice plant for its operation. It would naturally seem that if ice manufacturers appreciate the desirability of the gravity brine system under conditions of this kind, where they have a corps of engineers and everything convenient for the successful operation of a machine, it would be undesirable for an average person to undertake to run a plant of small or medium capacity without previous experience. It seems that those who know the most about refrigerating machines are the least anxious to undertake to operate them in connection with a cold storage plant, where uniformity of temperature and certainty of results are important.

Probably the majority of those present are familiar to some extent with the gravity brine system, the principles of which are so simple as to need very little study to thoroughly understand. The

details of construction are, of course, more or less complicated, depending on the purpose for which the plant is to be operated, etc., and need not be touched upon at this time. A brief description, however, may be permitted. Essentially, the system consists of a continuous pipe, a portion of which, in the form of a coil, extends through a tank or receptacle filled with a mixture of broken ice and salt, and another portion of which, exposed at a lower level, extends through the room or medium to be cooled. The pipe is first filled with brine of the proper density; the coil in the tank is surrounded with ice and salt; and the system is immediately in operation. The brine, being cooled in the tank, becomes heavier and circulates down into the portion of the pipe at a lower level and surrounded by a comparatively warm medium. Becoming warmer and lighter, it circulates upward into the portion of the pipe in the tank. Ice and salt being maintained in the tank, it will be readily seen that the circulation will be continuous. The system operates on the same principle as a hot-water heating plant, but in a reverse direction. The patent claims allowed on this system cover not only the gravity circulation, as described, but a circulation of brine under this arrangement by means of a pump. Temperatures as low as 10° Fahr. are obtainable with the system in practical operation, and a temperature of 6° Fahr. has been produced on a test.

The question which presents itself at this point is the comparison between a room cooled by the gravity brine system and a room cooled by direct expansion ammonia piping, or by brine piping cooled by expanding ammonia in connection with a refrigerating machine. What is the comparison? If the pipe surfaces of the gravity brine system which are exposed in the storage room are maintained at the same temperature as the ammonia coils or brine coils of the mechanical refrigerating plant, there need be no comparison. Results are identical. This point admitted, the gravity brine system takes its place on an equal footing with mechanical refrigeration, so far as results in connection with cold storage work are concerned, within the ranges of temperature through which it is able to work.

It is desired to point out some of the strong points which are largely or wholly inherent with the gravity brine system and cannot be claimed with equal force for mechanical refrigeration. These advantages may be considered under four heads:

First—Economy of operation.

Second—Safety against stoppage or breakdown.

Third—Ease and simplicity of operation.

Fourth—Uniformity of temperature and perfection of results.

Economy of operation depends, of course, largely on local conditions. There may be some places where the ice costs are so high as to make the system out of the question; but in connection with small or medium sized plants it is safe to say that, in a great majority of cases where cold storage is desired, the system can not only be operated for less but generally at a cost not exceeding half the expense of operating a refrigerating machine.

It is, of course, possible to pick out cases where a refrigerating machine would make a showing which would compare favorably with the gravity brine system. It is also equally possible to pick out innumerable cases where the system can be operated at one-quarter the expense of a refrigerating machine. Certain localities have power at a very low figure, and condensing water, if paid for, may be used for other purposes after use in the condenser. In most cases, however, power is high in cost, and condensing water must be bought at prevailing city rates and cannot be utilized further. The question of cost of attendance is a very serious one in some cases. On the other hand, ice is now obtainable at low rates nearly everywhere, even in the South, where platform deliveries seldom run above $3 per ton, and are often $2 or less. There is also much waste or broken ice obtainable at still lower prices. Some figures on cost of operation from plants actually in operation are given further on.

Under the head of safety against stoppage or breakdown it may be readily seen without any argument that the gravity brine system, having no moving parts, is absolutely sure against stoppage. Compare this with a refrigerating machine with a multiplicity of parts, and especially in unskilled hands, and the advantages of the gravity brine system are so apparent as to need no demonstration. In fact, there is not a single argument in favor of a refrigerating machine on the point of safety against breakdown. In connection with small plants, ranging in capacity up to several carloads, no machinery is required in the operation of the gravity brine system, as the ice may be broken by hand and raised to the primary tank with a windlass or hoist. In larger plants it is desirable to install a power ice-crushing machine and a chain-belt bucket elevator for elevating the crushed ice to primary tanks. The apparatus is all simple, and even in case of breakdown the ice may always be elevated to tanks in some other way.

Ease and simplicity of operation are always desirable, and in a small plant absolutely essential. The gravity brine system may be attended to by any man who will do as he is told, and there is nothing about the system which he can damage. The system is in fact

as near foolproof as a successful cold storage apparatus can be. It has been found in practice that after one season's experience any man of average ability, without previous mechanical or engineering experience, can handle a gravity brine plant so as to obtain the best possible results. Workmen of average intelligence have been known to carry rooms for the storage of eggs at a temperature of 29° or 30° Fahr. through the entire season after the house was filled, with a variation of less than half a degree. It is possible to cite a number of cases of this kind, and it is altogether certain that this cannot be said of mechanical refrigeration. It may be claimed that automatic thermostats, expansion valves, etc., have eliminated the necessity of skilled attendance, but the more experienced refrigerating engineers present will doubtless agree with the statement that instead of simplifying the operation of a plant these features really complicate it, and make liability of stoppage and breakdown still greater. The more apparatus added the more there is to get out of order.

Uniformity of temperature and perfection of results are especially important in connection with the storage of goods for long periods, and to a less extent in storing for short periods. The large volume of ice and salt in the primary tank and the large weight of brine and piping serve as a balance wheel to maintain uniform temperatures. When mixed with ice coarse rock salt acts slowly and regularly, and with tanks of proper depth the variation in temperature in a room filled with goods and reduced to correct carrying temperatures is so slight from day to day as to be unnoticeable on an ordinary thermometer. Even small plants show some remarkable records. The writer has personally operated egg storage rooms through the heat of summer with a total variation of less than half a degree. So far as primary means of refrigerating and its relation to perfection of results are concerned, uniformity of temperature tells the whole story. When possible perfection of results is discussed we immediately get into deep water and have to deal with conditions of humidity, air circulation, ventilation, etc., which is another story, and must be told at another time.

While not coming strictly under the head of cold storage by means of ice, it is desired to call attention to the chloride of calcium process for preventing frost on cooling coils, and at the same time purifying and drying the air of the cold storage room. This scheme was devised by the writer to meet a situation where it was impossible to clean the frost from the cooling coils. The scheme is extremely simple yet new, and when a patent was applied for, claims were allowed practically as drawn, and do not confine the process to any

particular mechanical details. It is only necessary to support chloride of calcium in such relation to the cooling pipes that the brine resulting from moisture in the air being absorbed by the calcium will trickle or drip down over the pipes. The benefits to be derived from this process are much more important than is apparent or readily understood without having used it. It is mentioned here for the reason that it is always installed in combination with the gravity brine system, and the writer fully believes that these two systems together constitute the most successful and satisfactory system for small or medium sized plants, and, in country locations where natural ice may be obtained at low cost, large plants as well.

A few suggestions as to the practical application of the gravity brine system to cold storage work may be of interest. Numerous plants are in operation where all the perishable goods usually placed in cold storage, as butter, eggs, cheese, poultry, meats, fish, fruits, beer, grocers' sundries, furs, milk, cream, ice-cream, ice, etc., are stored. This system was developed in connection with the butter and egg business, and more plants are in operation for the storage of these goods than any other. More recently, however, the system has been applied to a great variety of purposes. Several creameries and ice-cream factories have been fitted up; houses for the storage of fruit only; and a house for the storage of fruit trees and other nursery stock is under construction. Several pork-packing and provision plants have been installed, and in fact the cold storage field has been thoroughly covered. In connection with the creamery and ice-cream business the system is installed in connection with a large storage tank or reservoir for cold brine, the brine being cooled by gravity circulation and stored for quick action when wanted. This is especially applicable to milk and cream cooling coils and to continuous ice-cream freezers, and might also be applied to beer cooling in connection with brewery work. A cold storage plant was built adjacent to an ice plant and is cooled wholly by means of ice. Here is a suggestion for those who have had trouble in operating a few cold storage rooms in connection with an ice plant. It is expensive to keep the machine in operation during cold weather for the purpose of refrigerating the cold storage rooms only, and the system will, in such cases, be far more economical to run, and it will also produce more uniform temperatures and better results.

It is proposed to install the system for cooling a storage house for artificial ice located at a distance from the ice plant, to be filled with ice during cold weather, maintaining a temperature of 28° Fahr. It is also proposed to cool a storage room for artificial ice adjacent to

the ice plant, and to equip the primary tank of the system with direct expansion coils. When the ice plant is in operation the system will be cooled with direct expansion, and when the ice plant is shut down the system will be cooled with ice and salt in the regular way. It is perhaps unnecessary to suggest that this system is especially adapted to the use of the larger consumers of ice in the cities, such as ice-cream factories, butchers, commission houses, produce dealers, etc. Where the primary tank cannot be located above the storage room it is practicable to locate it at one side or one end of the room and raised only slightly above the space to be cooled; or the primary tank may be located in the basement and a small rotary pump used for circulating brine, as already suggested.

From time to time the advocates of refrigerating machinery have drawn comparisons between ice as a refrigerant and mechanical refrigeration. The unfairness of these comparisons is apparent. It is assumed, for instance, that ice will not produce temperatures below 38° to 45° Fahr. This is true of the average ice refrigerator, but not true of the gravity brine system. It is also assumed that ice costs all the way from $3 to $10 per ton. In natural ice territory ice may frequently be stored for less than 50 cents per ton during winter, and may be had as low as $1.25 per ton, delivered as wanted, during summer. It is assumed that electric power for operating ice machines may be had for 4 cents per kilowatt. In many cases the cost will be more than double this amount. It is assumed that 20,000 cubic feet of space will require, say, 4 tons of ice per day. It may require 4 tons of machine refrigeration, but not 4 tons of ice when used in the gravity brine system. Some actual figures from plants in service are here given:

A wholesale and retail meat market in Minnesota, with 40,000 cubic feet of cold storage space, some of it freezers at 15° Fahr., consumed but 553 tons of ice, costing $1.65 per ton, delivered as wanted, and 67 tons of salt, costing $7 per ton, during the entire year of 1904, a total of about 3½ cents per cubic foot per year.

A butter freezing room in Kentucky, of 1,700 cubic feet capacity, carried at an average temperature of 10½° Fahr. during the month of August, 1904, used but an average of 507 pounds of ice and 109 pounds of salt per day. An egg room in same plant, of 3,560 cubic feet, for the same period and held at an average temperature of 30° Fahr., required but an average of 790 pounds of ice and 132 pounds of salt per day. It is interesting also to note that the variation of temperature during the month, even under this first season of unskillful handling, did not exceed 1½° in either room. Ice

cost only $2.50 per ton delivered; salt, $7 per ton. The cost of operating the butter freezer per day in midsummer was $1.02, and the cost of operating the egg room $1.46 per day. This is less than half the earning capacity of this space at regular storage rates. These figures are not selected, but are the only accurate figures at present available.

In conclusion it may be stated that when a certain general scheme, like cold storage by means of ice, has been condemned by the best posted and most influential men in the business, the reinstating in public favor is a matter of very slow progress. Nevertheless, it is ventured to predict that there will be a change, and that ice will come into prominence and take its place as successful for cold storage purposes. Perhaps the gravity brine system will come into favor, or perhaps it will be some other system.

DISCUSSSION.

Allston Sargent.—What was the insulation in the Kentucky plant that was cited; I think it contained 1,700 cubic feet and required 500 and some odd pounds of ice per day?

Madison Cooper.—As near as I remember it was 8 inches of mill shavings and 2 inches of hair felt, supported by three thicknesses of boards and paper. There were an outside board, an 8-inch stud, a 1-inch board and 2 inches of hair felt, then inside lining of room and four thicknesses of paper.

Allston Sargent.—You cite a case, which I think is fairly accurate, of 20,000 cubic feet of space requiring about 4 tons of refrigeration per day. On about what insulation is that based?

Madison Cooper.—I do not know anything about that. That was on another man's figures; I did not make the figures.

Allston Sargent.—About what insulation would be required on those figures, 20,000 cubic feet, which figures out that 100 cubic feet will require 40 pounds of ice and 200 cubic feet 80 pounds of ice?

Madison Cooper.—Do you refer to where it is said that 20,000 cubic feet of space requires 4 tons of ice per day?

Allston Sargent.—Yes.

Madison Cooper.—That is based on what someone else has said.

Allston Sargent.—What would you think the insulation ought to be to melt that much ice?

Madison Cooper.—I do not think it would figure that much in the loss through the insulation.

Allston Sargent.—That means the insulation would require that amount of ice?

Madison Cooper.—I am not responsible for the figures. I have never had any experience which leads me to believe that 20,000 cubic feet would require 4 tons of ice.

Allston Sargent.—It would not require it?

Madison Cooper.—Not in my experience; it would take much less.

Allston Sargent.—I want to get at the economy of your figures. You state that 3,500 or 3,600 cubic feet would require 780 pounds of cracked ice and salt; dividing that into smaller units, it would figure out that one-eighth of the space would require about 100 pounds of ice; does it figure out to that economy in the gravity brine system?

Madison Cooper.—No; my judgment would be that it would take twice that amount of ice.

Allston Sargent.—But that is half as much as is required when ice alone is used, without the use of the gravity brine system.

Madison Cooper.—As I said, I am not responsible for the figures.

Allston Sargent.—One hundred cubic feet would require only about 13 pounds of ice per day.

Madison Cooper.—The proportion of ice would run up very rapidly as the capacity was reduced.

Allston Sargent.—In the case of the Kentucky plant, what would be the quantity of ice required, supposing the outside temperature was 38°?

Madison Cooper.—I should say off-hand that you would not use more than one-quarter of the ice; perhaps you would not use any at that time of the year, when the weather was cold.

Allston Sargent.—I wanted to find out whether the cracked ice and salt met somewhere. According to your figures it would require something like four times the amount of natural ice than when salt and cracked ice are used. There is no question but what a box of 450 cubic feet would use more than 100 pounds of ice a day.

Madison Cooper.—It probably would under those conditions.

Allston Sargent.—Would it not use a good deal more?

Madison Cooper.—Yes.

Allston Sargent.—Would it use about four times as much?

Madison Cooper.—No, about twice.

Allston Sargent.—How low can you go down? When does it cease to be economy?

Madison Cooper.—Explain what you mean by economy in that connection.

Allston Sargent.—According to these figures, a refrigerator 6 feet long by 2 feet deep by 5 feet high would require 100 pounds of ice, but only about 13 pounds of ice with some salt in it.

Madison Cooper.—I think I begin to see what you mean; you assume that ice and salt will be more economical than ice.

Allston Sargent.—You make a great saving by cracking the ice and putting salt in it.

Madison Cooper.—No; that is not true.

Allston Sargent.—Five hundred pounds of ice put in in the usual way, by the side-door system or overhead system, which you claim is not practicable, would not run a refrigerator of 1,700 cubic feet capacity.

Madison Cooper.—No; that is not true; there is no economy claimed in the consumption of ice with the gravity brine system.

Allston Sargent.—Based on your figures of 20,000 cubic feet, there is an economy of one-fourth?

Madison Cooper.—Those are not my figures; those are the refrigerating machine man's figures, where he tried to show it would take that much ice. I do not claim it would take 4 tons to cool 20,000 cubic feet. I have never seen any such case.

Allston Sargent.—It would really take more ice by your system than by putting it in in the usual way?

Madison Cooper.—Certainly it would.

Allston Sargent.—How much more?

Madison Cooper.—If you carry a lower temperature than ice alone will give, it would take more ice; besides that you have to pay for the salt. What is claimed for the system is that it will do any work that a refrigerating machine will do. We use a certain proportion of piping and the temperature is regulated by the amount of salt used.

Allston Sargent.—When you put in several hundred pounds of ice is it melted by next morning?

Madison Cooper.—No; it would melt down from 1 to 2 feet a day, or perhaps as much as 3 feet.

Allston Sargent.—On how small units have you tried your system?

Madison Cooper.—In some plants of less than 1,000 cubic feet.

Allston Sargent.—How much ice will it take a day?

Madison Cooper.—I do not know.

Allston Sargent.—Really, it would take more ice than the usual way?

Madison Cooper.—Yes; it would take more ice because there

would be lower temperature. That is the feature. If you maintain lower temperatures than ice alone will produce it will take more ice in proportion.

Allston Sargent.—The figures seem to be very low in the Kentucky case. It would seem to me that it would take more ice to do that, cracked ice and salt, than it would take in the natural way. I do not see how you arrive at the figures.

Madison Cooper.—Those figures are an actual record. The man that ran the plant made them. I did not make them.

Allston Sargent.—Have you any figures for September or October?

Madison Cooper.—Yes, I have, but I did not think it worth while to use them, because I used the warmest month in the year.

Allston Sargent.—That would be the best time, but I wonder how much ice it would take in the fall? If you took 500 pounds in August with a room temperature of 10½°, then take an outside temperature of 50° or 60°, it shows an enormous economy by using cracked ice and salt.

Madison Cooper.—As the weather became cold the consumption of ice would drop off rapidly and, as I said before, you would probably not use any ice at all at this time of year to carry a room at 30°.

Allston Sargent.—To carry a temperature of 10½° it would only take 1,700 pounds of ice; at a temperature, say, of 40° outside you would only take, according to your figures, 400 pounds of ice. Most any refrigerator would take a good deal more than 350 or 400 pounds of ice of that size, no matter how you built it.

Madison Cooper.—Perhaps, on the basis of using a refrigerator where they put in goods every day; but in a refrigerator where the goods are put in and they remain there, it is merely the holding of the temperature.

Allston Sargent.—Nothing put in during the period mentioned?

Madison Cooper.—No.

Allston Sargent.—Was it just a test?

Madison Cooper.—The room was full of goods, but no warm goods were put in.

Allston Sargent.—The test would run for one month?

Madison Cooper.—Yes.

Allston Sargent.—Did you not take a test for twelve months?

Madison Cooper.—No, but we have records covering the entire summer.

Irving Warner.—Brine tables give us a certain temperature at which a certain percentage of salt and water will freeze; I suppose

the melting temperature is the same thing; that is, 7 per cent. salt would freeze at about 24° Fahr. Was that your melting temperature?

Madison Cooper.—I suppose that would be true.

Irving Warner.—Then, as compared with these tables, how many degrees would you use in the room, according to the way you would count it, economically, with reference to the circulating of the brine of that percentage?

Madison Cooper.—I cannot answer that question. I have no records of that kind. I might explain the same thing in another way, perhaps. The room can be cooled within about 5° of the temperature of the brine, assuming that your figures are correct, which they probably are. It would be a fact that you could cool the room to within 5° of the melting temperature.

Irving Warner.—There would be one or two degrees difference, I suppose, between the temperature of your primary ice and brine and the temperature of your secondary coils. There ought not to be much.

Madison Cooper.—I presume there would be that much, perhaps more.

Irving Warner.—What disposal do you make of the brine that you obtain from the melting of the ice?

Madison Cooper.—We do not allow the brine to stand in the primary tank. It runs to waste as fast as it forms. We carry it through a small coil in the space to be cooled and allow it to be discharged. We do not reclaim the salt.

Irving Warner.—I suppose it could be used for the cooling of an ante-room?

Madison Cooper.—Yes; we frequently pipe it through a cold storage room and then utilize it in a comparatively high temperature storage room that is used for candling eggs or anything of that kind, or for temporary storage.

Irving Warner.—I notice in your figures that the cost of salt represents about 35 or 40 per cent. of the total expense. Now your greatest consumption of ice and salt occurs in the summer time, when it would be most easy to evaporate the water and obtain the salt. Did you ever try that?

Madison Cooper.—No; but it is not practicable. There is nothing in it. It cannot be done. I figured it over in different ways. About the only utilization of the ice and salt brine is in connection with packing-house plants. They use it as far as they can for pickling meats after it is strengthened to the right point.

Irving Warner.—Does it have a very high density?

Madison Cooper.—It depends upon how hard the plant is being crowded.

Irving Warner.—When you are salting the ice the most, the brine is of the highest density?

Madison Cooper.—Yes, when you crowd the apparatus hardest the proportion of salt would be greatest.

Irving Warner.—Have you introduced any automatic device to regulate the secondary brine so as to keep the room at a certain temperature, or do you depend upon having your system designed liberally enough and then mixing indefinite proportions of salt and ice?

Madison Cooper.—We have no automatic features. The temperature is regulated by the quantity of salt used and no attention is paid to the proportion of salt and ice. That will take care of itself. A plant must be designed with pipe surface enough to do the work in warmest weather or when the greatest amount of refrigeration is required. In cold weather it is only a question of using less salt, as there is less work to do. The practical scheme is that the less salt is used the less ice is melted and the higher temperature obtained, and the reverse is when more salt is used and more ice melted and a lower temperature obtained or more refrigeration produced. The salting is really the main idea of the whole thing, so far as regulating the temperature is concerned.

Irving Warner.—Did I understand you to say that you did not weigh the salt with any reference to the weight of ice?

Madison Cooper.—We pay no attention to the amount of ice. Use a certain amount of salt that is necessary to get the results and the ice will take care of itself.

Irving Warner.—It is evident that if you make the amount of salt too large the temperature is reduced much lower right away.

Madison Cooper.—In practical operations we would use a certain amount of salt daily. The practical method is to have pails holding a certain quantity of salt, and to use a certain number of pails on the tank each day. If the weather becomes warmer, use a little more salt; if cooler, less salt.

Irving Warner.—Do you also use a certain amount of ice?

Madison Cooper.—Pay no attention to the ice; keep your tanks full of ice all the time and use the quantity of salt required to get your temperature under the conditions.

Irving Warner.—I am not well acquainted with the cold storage proposition, but I suppose there is always so much cubic capacity

for so much cubic feet volume, whereas the radiating surface is more nearly proportional to the square of any given dimensions. Do you usually count on the volume or radiating surface?

Madison Cooper.—The practical way is to take cubic capacity. Of course, if you want to figure it out in conduction it would be necessary to take exterior surfaces. Practically, the volume is sufficient.

Edgar Penney.—Can you satisfactorily explain the action of salt on ice? Have you a table showing the relative quantities and the corresponding temperature; how many heat units would be liberated with specific amounts of salt and ice?

Madison Cooper.—I have no such tables. I wish I had. I have tried to get them, but I do not know where they are to be obtained.

Edgar Penney.—I did not know but that you, being so specifically interested, had made experiments to ascertain these data.

Madison Cooper.—I have not.

Edgar Penney.—It would be interesting to me to be informed of the exact theory of freezing mixtures. There are many known mixtures for producing low temperatures covering a large range. As you are using such mixtures to secure practical results, I am disappointed that you cannot explain the interaction of the two simple elements that you bring together to secure your results. I should think this specific knowledge would be the necessary basis of your whole scheme, so you could intelligently make up your mixtures of ice and salt to liberate a given amount of heat units.

Madison Cooper.—That is true, but I have to confess ignorance.

Edgar Penney.—I think you should experiment, make a table and ascertain the quantities and the temperatures.

Madison Cooper.—My work has been based on practical lines, rather than on theory.

Edgar Penney.—That experiment would not be very theoretical, but would be right in line with your own business and you would know what the possibilities are and how near you would measure up to what ought to be.

Madison Cooper.—The point is well taken.

Edgar Penney.—Referring to insulation, if you could insulate a room so thoroughly that there would be no transfer of heat the problem would be very simple. You have given figures as to the amount of ice and salt that you have used, and in your system you regulate the temperatures or the refrigerating work by the amount of salt. Now it seems important to know just how much salt is

to be put in the ice. The salt promotes the melting of the ice in a very peculiar way and it has always been fascinating to me to know just why it did so. Probably some of the gentlemen present can explain that matter to our satisfaction.

Allston Sargent.—What size primary tank do you use for 1,000 cubic feet capacity?

Madison Cooper.—Roughly, a tank 2 feet by 4 feet by 6 or 7 feet deep, what we call a one-coil tank. It would be away out of proportion to what a larger one would be. There are purely practical reasons. The tanks must be made large enough for a man to get down in them and clean them out, and also to put in the pipe work.

Gardner T. Voorhees.—The question that has been raised by Mr. Penney appeals to me. I wonder if it could not be explained in this way: You have a certain size refrigerating machine to compress a certain number of cubic feet per revolution, to refrigerate a certain room at a certain back pressure. You would run that machine at a certain number of revolutions. It appears to me, in Mr. Cooper's system, that he simply wants to use a certain amount of salt, and the salt melts the ice, to keep the room at that temperature, and adding a certain amount of salt would be equivalent to running the compression machine faster or slower. I have always thought that Mr. Cooper's system, where natural ice was available, would be an excellent thing. If you had to make your ice by refrigerating machines it would cease to be economical, so I would think that for saving the cost on a small refrigerating plant, or where a man has the natural ice, the gravity system would be a good thing.

Irving Warner.—Continuing on the point brought up by Mr. Penney, it seems to me that the question of the salt is merely to get the temperature desired. As Mr. Cooper says, there would be a probable loss of several degrees between the melting temperature of the ice and the temperature he gets in the room. If an operator wants a temperature of, say, 25° in his room, then it is evident that he has got to have a melting temperature in his primary tanks of somewhere in the neighborhood of 18°, and the only possible way of getting that is by making the salt melt the ice at that lower temperature. There would not possibly be any economy of ice melting. Ice can only absorb so much heat in melting—regardless of what temperature it may melt at. We know that steam, for instance, in being generated from water does not take a very great difference in heat absorption between boiling at 212° and boiling away up at 350°. We know there is a difference, but it is not

excessive. If we take ice, the difference of a few degrees should not make any difference in its heat absorption when melting, and so I should think we could say that the amount of heat absorbed by the ice would therefore be the cooling value of the ice less what it would take to reduce the sensible heat of the ice from what it started at down to what the primary brine comes off at, and I should think the amount of salt, in any case, supplied to the ice would be according to the temperature desired and not according to how fast the ice melts.

Edgar Penney.—The proposition resolves itself down to this as a problem. You place in one of your cold storage rooms, say, a ton of ice. The ordinary internal circulation of the atmosphere of the room over the ice causes it to melt at the rate of so many pounds per hour, depending upon conditions of temperature, and liberates an equivalent number of heat units, but does not secure low enough temperature. You resort to the use of salt, which furnishes a ready means for facilitating more rapid melting of the ice, and consequently you get more work from the ice in a given time. The function of the salt is to hasten or promote the melting of the ice; to melt two pounds, as it were, where the atmosphere would naturally melt but one, according to the mixtures. This makes a very simple way of regulating the quantity of ice to be melted in a given time and, consequently, the room temperature. What I have asked is, How do you explain the action of the salt upon the ice? Is it mechanical, chemical, or what? The salt is melted as well as the ice. Is latent heat liberated in the melting of the salt? Can you not make some experiments to determine the amount of ice that can be melted per hour to varying proportions of salt, and make records of the temperatures? We probably know what the lowest freezing temperature of a fully saturated solution of salt and cracked ice is. We desire to know the intermediate temperatures and quantities.

Thomas Shipley.—So far as I can see, nothing has been brought out by Mr. Cooper's paper that will endanger the future of the ice machine. We will all agree that it is the work done in the rooms and spaces being cooled that governs the amount of refrigeration required to do the cooling. I have seen many 20,000 cubic foot spaces and rooms which took much more than 4 tons of refrigeration to do the cooling work required, and so have the most of us. In Mr. Cooper's system he has the advantage of being able to offset an extraordinary demand by putting in more ice and salt; in fact, the only limit to the capacity of his system is the amount of ice and

salt he has at his command. He could do 40 tons work in his 20,000 cubic foot house if he had a large enough ice and salt pile handy.

Mr. Cooper is doing what we used to do twenty-five years ago when putting in refrigerating plants. We provided against the possibility of a breakdown by putting in a double brine tank; one containing the refrigerating coils and the other so arranged that when the machine was shut down it took care of the cooling work by putting ice and salt into it and circulating the freezing mixture thus made instead of the brine cooled by the machine.

When putting in a machine to cool a certain space it must be large enough to take care of the maximum amount of work to be done in that space at any time. With Mr. Cooper's system the rate of consumption of ice may range from 1 ton to 50 tons per twenty-four hours, and still the consumption of ice per twenty-four hours will only be 3 or 4 tons. A refrigerating machine, however, would have to be large enough to do the maximum work.

Mr. Cooper does not have to estimate or guess at the amount of work done in twenty-four hours. He simply fills up the tank with ice and salt whenever they are required.

F. E. Matthews.—I wish to ask Mr. Cooper what temperature he had: he simply stated 20,000 cubic feet.

Madison Cooper.—I have not the figures, but I think it was 40°.

F. E. Matthews.—I have just made some rough calculations to determine how nearly Mr. Cooper's example came in line with average practice. Assuming the 20,000 cubic feet was in the form of a cooler 15 by 30 by 45 feet, we would have 4,950 square feet of superficial surface.

Now the wall duty is equal to the superficial surface times a constant K, involving the difference in temperature and the value of insulation, or, K = pounds duty divided by square feet. If the duty is 4 tons or 8,000 pounds, and the square feet is 4,950, K will equal 1.6 +, or for a difference in temperature of 90 — 40 = 50° Fahr. it will call for duty a little better than 5 B. T. U. per square foot, including product as well as radiation duty, which is quite in line with average practice.

Louis Block.—Mr. Cooper, have you had any experience in cooling rooms at different levels with your system?

Madison Cooper.—Different floors?

Louis Block.—Yes, sir.

Madison Cooper.—Yes, sir.

Louis Block.—How have you been able to regulate the temperature of the different floors?

Madison Cooper.—Each floor has its own separate tank; so has each room.

Louis Block.—Do not use any valves at all?

Madison Cooper.—No.

Louis Block.—That would be rather expensive for a large house, would it not?

Madison Cooper.—It would be somewhat more expensive, but it gives a better control on account of giving a separate tank for each room, and controlling each room by itself.

Allston Sargent.—There is one point that I have not got settled yet, although I have tried once or twice. I would like to get from Mr. Cooper a comparison between his system and the use of ice. We will assume that you can use ice by putting it in at the side of the chamber or overhead. Take, for instance, your example of 1,000 cubic feet of storage space; you use a primary tank about the same height as the ice chamber would be.

Madison Cooper.—That might be approximately correct.

Allston Sargent.—If you put ice in the tank without the addition of salt and cool the room to 42° what is the difference? Does your system use more ice with the same insulation, or would it be less where ice was used alone?

Madison Cooper.—There would be absolutely no difference.

Allston Sargent.—There would not be any difference by putting salt in the cracked ice and by putting the ice in in the natural way and cooling to 42°?

Madison Cooper.—To cool it to 42° you would not use any salt with the gravity brine system.

Allston Sargent.—It is not good for anything above freezing?

Madison Cooper.—If you care to you could put it that way.

Allston Sargent.—It would use more ice above freezing?

Madison Cooper.—No; the results would be the same—the same temperature, the same amount of ice.

Allston Sargent.—There would not be any advantage above 32°.

Madison Cooper.—Excepting the advantage of a dryer atmosphere and the control of temperature.

Allston Sargent.—That would be regulated by circulation.

Madison Cooper.—Of brine?

Allston Sargent.—No, of air.

Madison Cooper.—No; with ice alone you are limited to the temperature ice will produce. You get only 38° or 40°. The advantage of the gravity brine system with temperatures above 32° would

be to control the temperature and give a dryer air in the room. Where you circulate air over the ice there is a constant humidity.

Allston Sargent.—Would the coils make a dryer atmosphere than the ice alone?

Madison Cooper.—Yes; they would draw the moisture out of the air.

Allston Sargent.—By putting the coils in in the usual way, no matter where you put them, unless in a bunker, you would find it damp most of the time, unless you circulate the air.

Madison Cooper.—Where would the coils be?

Allston Sargent.—Right in the room.

Madison Cooper.—Whereabouts in the room?

Allston Sargent.—Hanging from the walls and the ceilings. That would not produce a dry temperature in a room 8 feet high, would it, without any circulation? When you open the doors moisture would condense.

Madison Cooper.—Without any doubt there would be sufficient circulation in a small room.

Allston Sargent.—A room containing a thousand cubic feet would not be dry.

Madison Cooper.—Perhaps not in your experience.

Allston Sargent.—Then you could not get a dry atmosphere with the gravity brine system above 32°.

Madison Cooper.—I can explain along that line. We always install a chloride of calcium process; when there is any question of the dampness we use chloride of calcium.

Allston Sargent.—You could not dry it any other way.

Madison Cooper.—Not in any other way than by using the calcium.

I would like to answer Mr. Penney's question as near as possible. I do not believe there are any figures available showing the absorptive power of ice when used with salt. At least I know of none; but it is my impression that a mixture of ice and salt will produce more refrigeration than the melting of the same quantity of ice without salt. I believe salt would add refrigeration to the mixture.

Chairman Starr.—That would imply that there was latent heat taken out.

Madison Cooper.—Yes; there must be some chemical or physical action between the moisture in the ice and the salt itself.

Chairman Starr.—I should think it would be a simple thing to find out the rate of melting and the resulting temperature; it

would be of great interest to the refrigerating engineer to have such a table.

Gardner T. Voorhees.—I believe that is simply a physical proposition. You would get just as much less as was required to cool the salt. That is, you get 144 thermal units from a pound of ice, minus what it took to cool the salt. I believe it would give a little less refrigeration than it would without salt. Probably that would be a small amount.

Edgar Penney.—I might ask Mr. Voorhees if he believes there is no taking up of heat.

Gardner T. Voorhees.—I understand that salt melts in water and does not generate heat the way calcium chloride does. I think it is a question of dissolving it. If you take a pound of salt at 32°, put it in a pail of water at 32°, and there is no loss of heat, the resulting mixture would be 32°.

Madison Cooper.—I can answer that question, I think, from an experiment made some years ago. I took a pail of water at a given temperature and salt at the same temperature, and mixed them together and got a drop in temperature of several degrees.

Louis Block.—That is my experience also.

John A. Ruddick.—I have some personal knowledge of some of the gravity brine systems that are in use in Canada, and for certain classes of storage they seem to have given very excellent satisfaction. I have been particularly impressed with the usefulness of the system for the storage of eggs, because I have known no storages where the temperature is kept so uniform, say near one point, as it is in those places where the gravity brine system has been installed. I heard Mr. Cooper state that the rooms have been kept for the summer, after they had been filled, without a variation of more than half a degree, and from my experience I quite believe that.

In my country we have depended a great deal upon ice refrigeration for certain purposes, because ice is cheap in most parts, although, no doubt, it will surprise some of you to learn that there are parts of Canada where they do not get a pound of natural ice, on the west coast; but in eastern Canada we have generally a fair crop of ice, as well as of many other good things, and we can harvest it at a very low rate.

I believe it is possible to put up ice, where the ice house is situated alongside the source of supply, at less than 50 cents a ton. I have contracted for ice at less than that. The price would vary according to the ease with which the supply could be obtained.

We have tried, in our creamery refrigeration, both the circulation system, as I call it, and the direct tankage system mentioned by Mr. Cooper; but we have not found the direct tankage system, where the cracked ice is put in retorts in the storage room, to work out very satisfactorily. I will not go into that. We recommend our creameries, where they have installed artificial refrigeration, to put in the circulation system where you have two chambers both insulated, one for storage and the other for ice, and the air circulates between the two, over the surface of the ice. We have found that to be the best system for creameries. I am not comparing it with the gravity brine system, which, with the use of salt, will undoubtedly give a lower temperature. I am glad to say, from the experience I have had and the inspections I have made of a number of these gravity brine systems, that they seem to give much satisfaction, especially where ice can be obtained at a low price.

No. 40.

RECENT INVESTIGATIONS IN THE HANDLING OF PERISHABLE PRODUCTS FOR TRANSPORTATION.

By S. J. Dennis, Expert in Refrigeration, United States Department of Agriculture.

(Non-Member of the Society.)

For several years the United States Department of Agriculture has devoted considerable attention to the handling of citrus fruits for transportation, with a view to determining the causes for the frequently serious losses in transit and in storage. These investigations, which have been carried on in the citrus fruit districts of both California and Florida, have been during the past season considerably extended in scope, and a brief résumé of the results obtained will, it is hoped, be not without interest to some of the members of this Society.

While several of the points touched upon lie outside the field of the refrigerating engineer, they are nevertheless of considerable importance by reason of their direct bearing on the keeping quality of oranges to be handled by the cold storage man. The experiments conducted by the Agricultural Department with a number of commercially important fruits justify the broad general statement that the handling to which fruit is subjected before storing is likely to be the leading factor in determining its keeping quality in storage. Two lots of fruit of the same variety and grown in the same locality may differ very materially in keeping quality as a result of different methods of handling before arriving at the storage warehouse. It may be further stated as an axiom that the less fruit is handled and the greater the care used in handling the smaller will be the loss by decay. It has been the work of the department to demonstrate that care in this respect will be amply repaid. This applies equally as well to the orange as to some other fruits apparently more susceptible to injury by rough handling. That it does so apply has not been entirely realized by the orange growers in the past; but, as a result of investigations already completed, the growers and shippers are rapidly falling into line in the adoption of improved methods of handling. It probably is not too much to say that as soon as the facts can be sufficiently impressed upon those concerned an appreciable improvement in the keeping quality of oranges may be looked

for. A systematic effort to accomplish this is a part of the projected work of the Department of Agriculture.

The experiments have established firmly the fact that an orange with a sound whole skin is highly resistant—in fact, almost immune—to fungous attack. The slightest abrasion of the skin, however, immediately makes the fruit vulnerable. The methods of handling commonly used have been found to be responsible for slight mechanical injuries to the skin, which, in themselves entirely unimportant, were extremely serious by reason of the opportunity afforded for the entrance of mould spores. Processes of handling which increased the chances for the inoculation of such injured fruit with mould spores have been found to be directly responsible for a marked increase in decay. An orange with an abrasion of the skin and the injury inoculated with mould spores means sooner or later a decayed orange, if the spores are supplied with the moisture requisite for their growth. Brushing or washing the fruit, either to remove the bloom and give somewhat of a polish, or to remove the black smut which results from the presence of the scale insects in the groves, has been found, particularly the washing, to be a very efficacious means for the distribution of mould spores, and a change in practice is already noticeable. Keeping down the scale insects by spraying the trees eliminates the necessity for washing, and it is often found that the brushing may also be dispensed with.

At present the greater part of the oranges are shipped from California under two general systems, namely, ventilation and icing. In the winter and early spring, when temperatures are low, the fruit is shipped in refrigerator cars with the ventilators left open, so that a current of air circulates through the car when in motion. Later in the season, when temperatures are higher, the ventilators are closed and the tanks at the ends of the cars kept filled with ice. The matter of precooling or quickly lowering the temperature of the fruit before shipment has been attracting much attention, and a considerable percentage of the southern California crop has been shipped commercially under this system during the past season, besides the experimental shipments by the Department of Agriculture.

To determine the bearing of the different methods of handling and shipping, and the keeping quality of the fruit after arrival in the Eastern markets, also the effect of delayed shipment upon the losses by decay, a quite comprehensive series of shipping experiments have been conducted. In these experiments fruit handled by the different processes has been held for varying lengths of time at the packing houses and the decay on arrival at New York care-

fully ascertained. The results of these experiments will be quite fully set forth in a bulletin* which is in process of publication by the Bureau of Plant Industry of the Department of Agriculture.

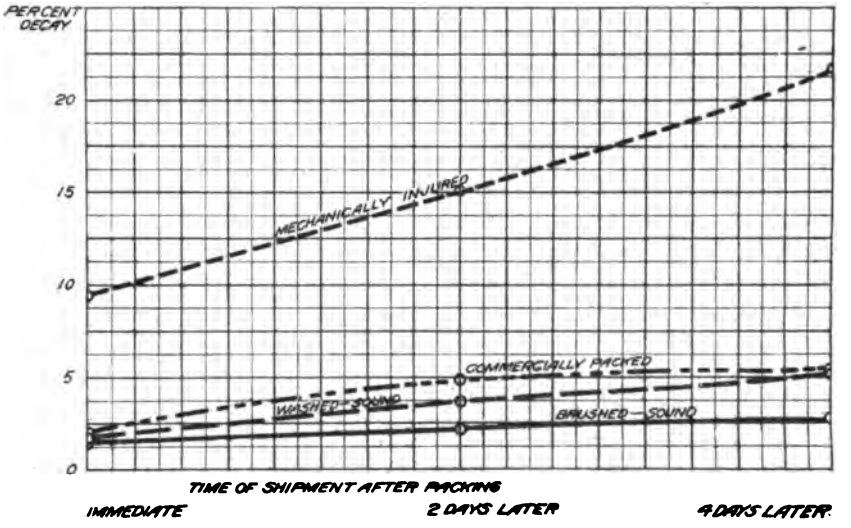

FIGURE 1.—Diagram illustrating the percentage of decay in oranges handled with average care, shipped from California to New York under ventilation, February, 1907, showing the effect of delaying the shipment after the fruit is packed. The effect is most pronounced in fruit showing mechanical injuries. Commercially packed oranges usually contain some mechanically injured fruit.

Briefly, these results may be summed up as follows: Perfectly sound fruit, either brushed or washed, invariably showed less decay than was found in the regular commercial output of the packing houses, indicating that there is a considerable opportunity for improvement in the methods of handling. Fruit known to be mechanically injured invariably showed a relatively very high percentage of decay, indicating that mechanical injuries are responsible for a large proportion of the decay in commercial shipments. An examination of the commercial output of a number of packing houses shows that such output very generally contains a considerable percentage of injured fruit. In all these classes the decay was materially increased by delay in shipping, the decay increasing

* Bulletin No. 123, entitled "The Decay of Oranges While in Transit from California," issued March 31, 1908, by the Bureau of Plant Industry, United States Department of Agriculture.

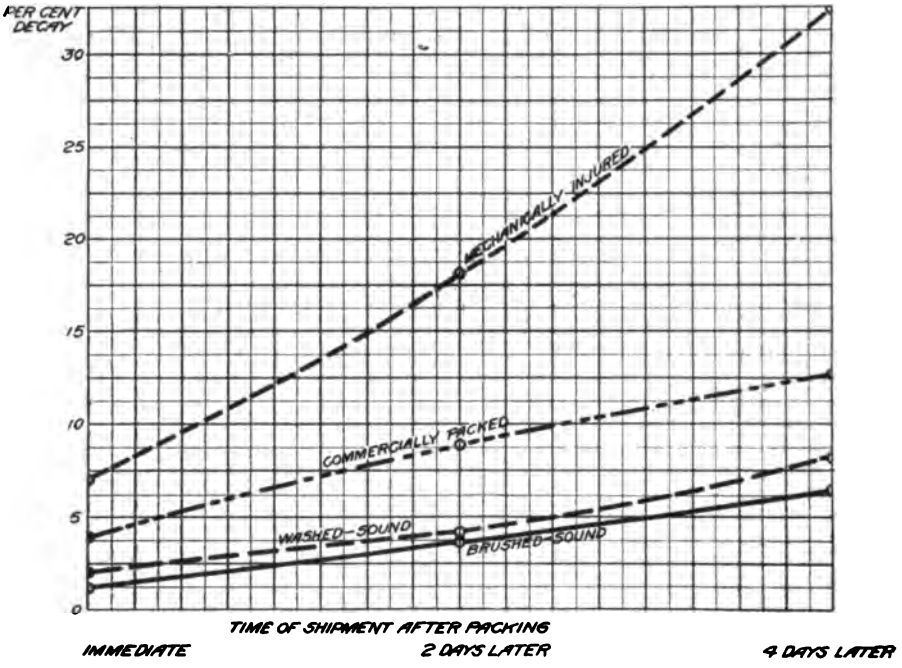

FIGURE 2.—Diagram illustrating the percentage of decay in oranges handled rather roughly, shipped from California to New York under regular icing, February to April, 1907. The fruit which is handled least and is most promptly shipped shows least decay.

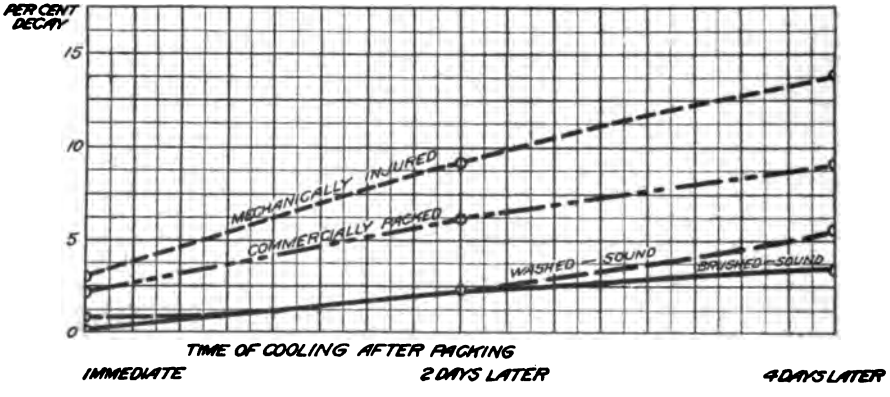

FIGURE 3.—Diagram illustrating the percentage of decay in oranges cooled before shipping, March to May, 1907. Delay in cooling increases the decay, especially in fruit showing mechanical injury to the skin.

nearly directly with the length of the delay before shipment. The increase in decay due to delayed shipment was least in the most carefully handled fruit and was by far the greatest in that mechanically injured. The commercial output again shows results intermediate between the two extremes.

Shipments under ventilation showed the least decay in all the classes experimented upon, and the effect of delayed shipments, although of the same character, was also less marked than the shipments under either icing or precooling. This is accounted for by the natural lower temperatures which prevail during the greater part of the season when ventilation is practiced. This comparison is not especially significant, however, as neither icing nor precooling is required during the ventilating season. Under precooling the results were distinctly more favorable than under icing, and where the handling of the fruit had been of the average type the precooling showed the most decided gain in the case of the mechanically injured fruit. However, tests conducted later in the season, with fruit more carefully handled and shipped under icing, showed considerably less decay than in the precooled fruit which had received the average handling. The reduction of the decay in the

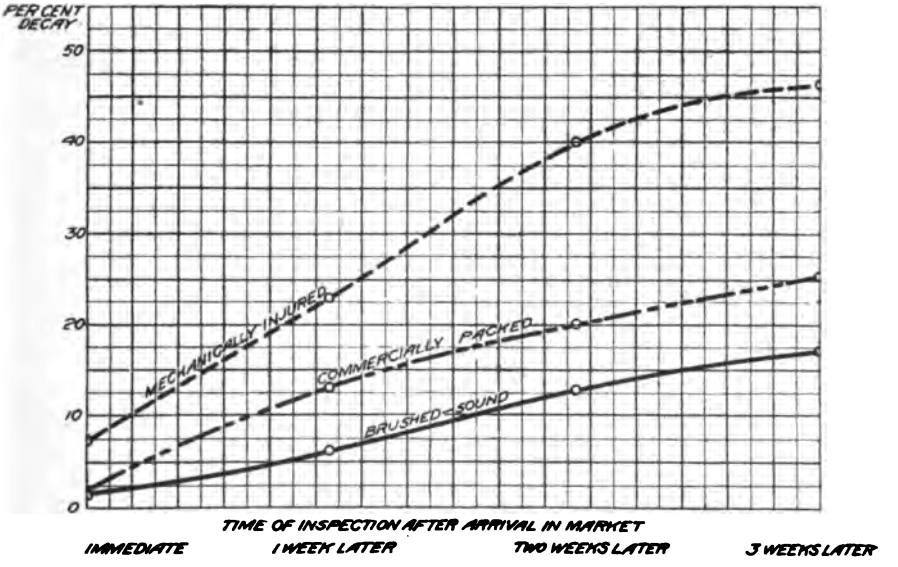

FIGURE 4.—Diagram illustrating the percentage of decay upon arrival in market, and for three weeks thereafter, of oranges handled roughly, shipped under ice, 1907.

commercial output due to careful handling was particularly noticeable.

Holding tests made in a commission house in New York, conducted with fruit which had received the average handling and shipped under icing, gave similar results. The most carefully handled fruit not only showed the least decay on arrival in New York, but the development of decay during the holding tests was also least rapid and was considerably less than in the commercial output of the packing houses. The mechanically injured fruit again showed the most rapid development of decay. Tests conducted later with the product of packing houses, where improved methods of handling had been introduced, the fruit shipped under precooling showed a very striking improvement, both as regards decay on arrival and a very much smaller increase of decay during the period the fruit was held at the commission house. The commercial output in this case showed very little more decay than was found in the fruit which had been selected as being apparently perfectly sound and uninjured.

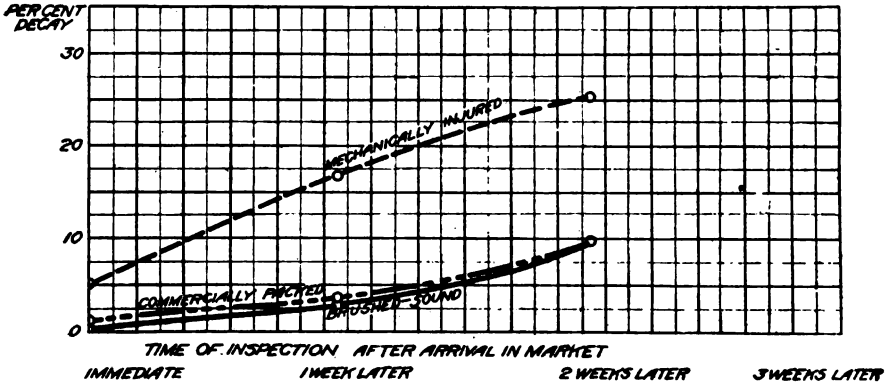

FIGURE 5.—Diagram illustrating the percentage of decay upon arrival in market, and for two weeks thereafter, of California oranges handled carefully and cooled to 35° or 40° Fahr. before shipment, 1907.

The temperatures of fruit in transit have been further investigated during the past season, and it is found that in all cases the temperature changes are invariably slow, five to seven days generally elapsing before the fruit in an iced car reaches a temperature low enough to interfere materially with the growth of the destructive moulds. It is during this interval that the damage is done and it is this damage which has led to the introduction of precooling as a means of reducing such losses.

Under precooling it has been found possible to increase materially the carrying capacity of the refrigerator cars. Under icing or ventilation the capacity is restricted by the necessity for leaving spaces between the boxes for air circulation. Also the height of the load in the car is limited by the higher temperature in the upper part of the car. Under precooling, the fruit being already refrigerated, air spaces are considered unnecessary, except along the car

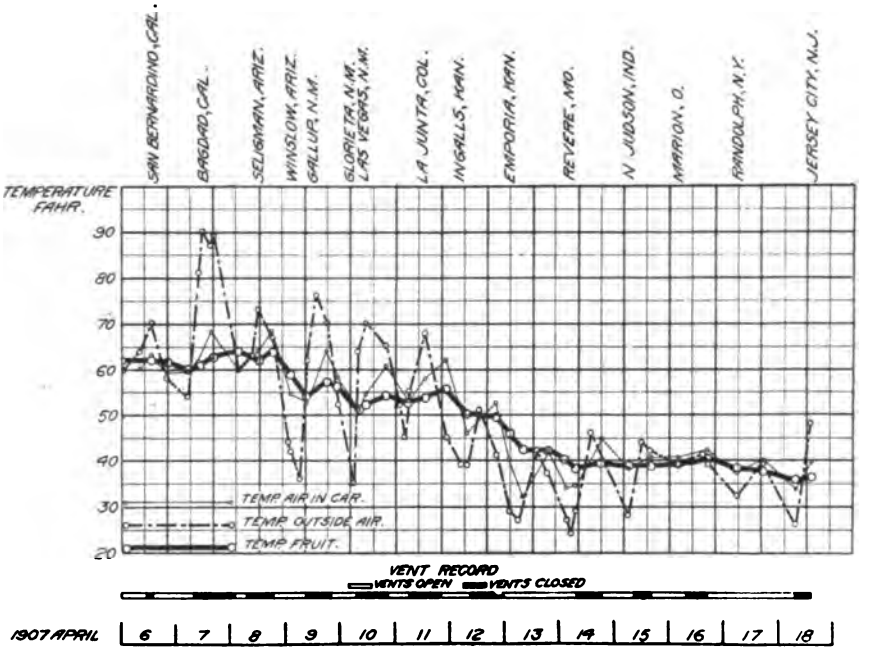

FIGURE 6.—Diagram showing the temperature record of a carload of oranges shipped under regulated ventilation, April, 1907. The ventilators were opened whenever the outside air was colder than the fruit, and were closed whenever the outside air became warmer than the fruit. The ordinary practice at present is to keep ventilators open at all times, except when the temperature falls below 32° Fahr., when they are closed.

walls to allow for absorption of the heat filtering through from the outside. It is also possible to increase the height of the load in the car, the total load in some cases having been increased by over 40 per cent. This increase in capacity under precooling is a feature which has attracted the attention of shippers during the car shortage of the past season. Fruit in cars so loaded has reached New York in excellent condition during the past season, but the temperatures

of the fruit, especially in the upper added tier, will probably require some further watching in hot weather before the entire practicability of the method is assured.

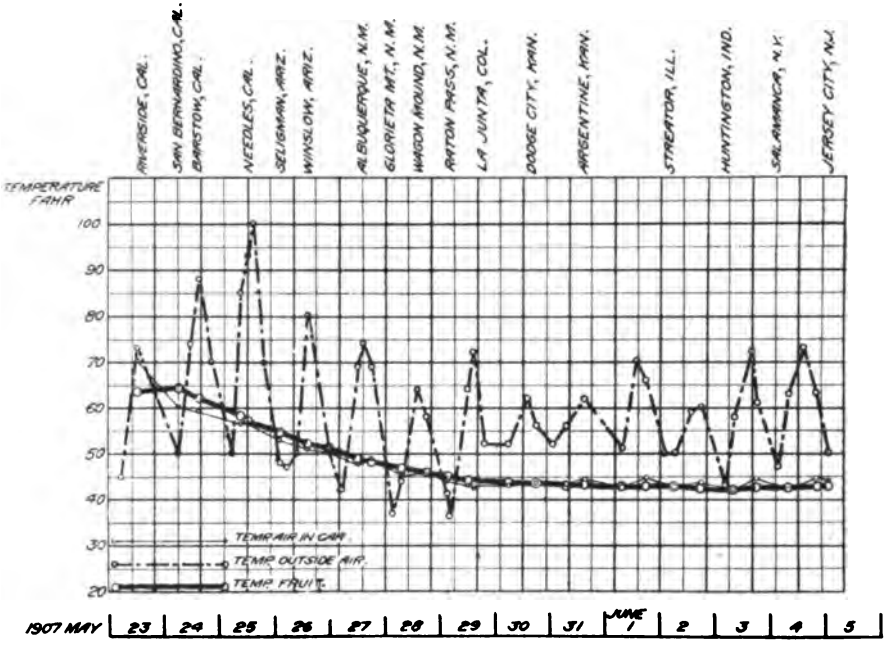

FIGURE 7.—Diagram showing the average temperature record of two carloads of oranges shipped under regular icing, May, 1907. Several days elapse before the fruit is sufficiently cooled to check decay.

While the improvement which has been found possible through careful handling is greater than the gain under precooling, yet the results obtained with precooling are such that the interest of the orange men has been strongly aroused and the system will undoubtedly be employed commercially to some extent in California during the coming season.

The precooling problem seems likely to demand considerable attention from the refrigerating engineer. If the system comes into anything like general use, as now appears entirely possible, a considerable number of special plants will be required. While there is nothing new in the principle involved, yet in the designing of these plants a number of problems will be encountered. Some of the questions which are arising and which are being asked by those interested may be mentioned. If precooling is to be generally em-

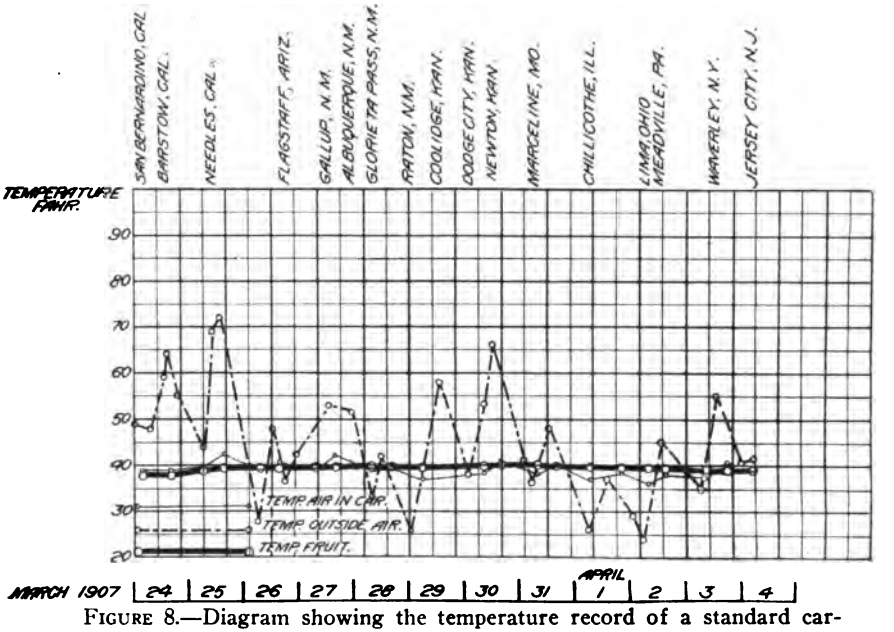

FIGURE 8.—Diagram showing the temperature record of a standard carload of 384 boxes of oranges, precooled and shipped under regular icing, March and April, 1907. The temperature of the fruit remained practically constant throughout the trip.

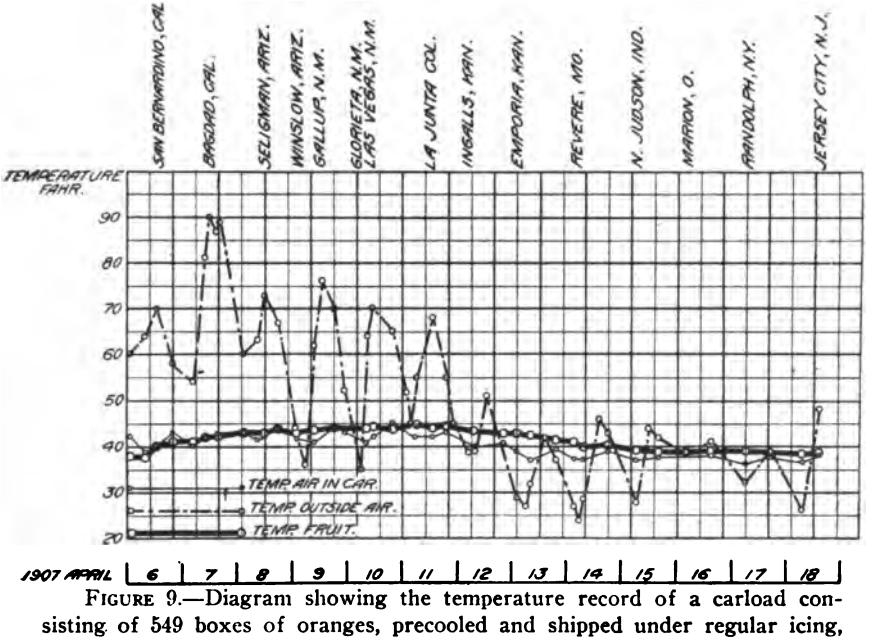

FIGURE 9.—Diagram showing the temperature record of a carload consisting of 549 boxes of oranges, precooled and shipped under regular icing, April, 1907. The usual carload consists of 384 boxes. The rise of the fruit temperature in the first few days of the trip indicates that if the outside air temperature had continued at a high average during the latter part of the trip the fruit temperature might have risen higher than is desirable.

ployed, should large central precooling stations be erected to which fruit may be shipped for precooling from the packing houses in adjacent territory or must the individual packers equip themselves with cooling plants? Will the greater economy of the large central

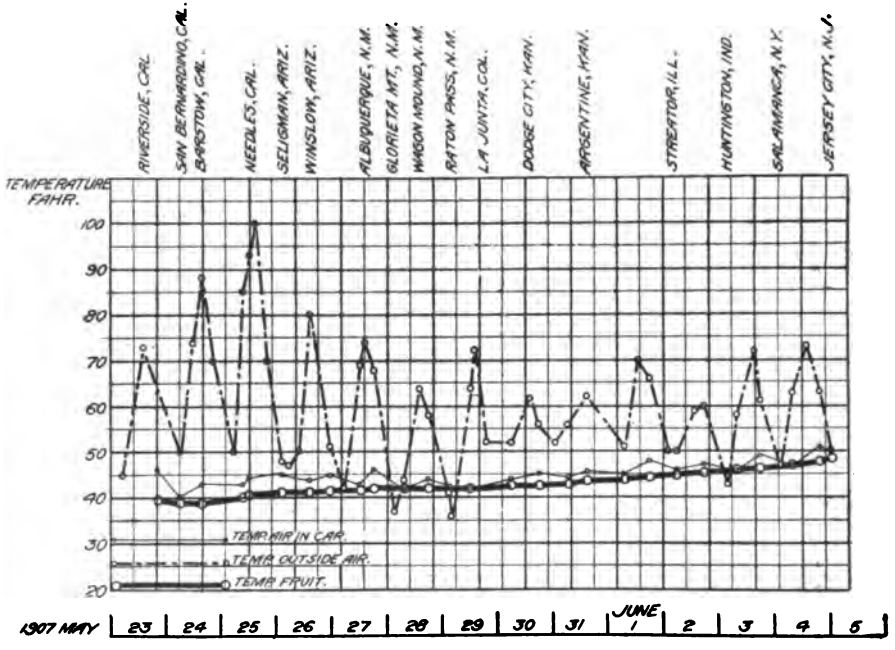

FIGURE 10.—Diagram showing the temperature record of a carload of oranges, precooled and shipped under initial icing only, May and June, 1907. The weather being cool during the latter part of the trip, the fruit temperature rose very slowly and was below 50° Fahr. on arrival at New York.

station compensate for the additional hauling and handling required? On the other hand, can the packer afford to invest in an expensive plant which will be in use for only a few months during the year? Or could such a small plant as the packer required be utilized during the idle months for making ice to be stored and used later for icing the cars or to increase the refrigerating capacity of the plant during the peak of the load? In the case of the individual plants, how much could be gained by employing a central refrigerating plant, distributing refrigeration by pipe line to packing houses at not too great a distance?

In any case what type of cooling plant should be employed? Should it be a warehouse with rooms in which packed fruit is placed for cooling, or should it be arranged to cool fruit already

loaded for shipment in refrigerator cars? Can the fruit be cooled in cars effectively and with sufficient rapidity to avoid objections on the part of the railroad companies to having their cars delayed and held for hours at a time on a siding? Can the fruit be cooled as quickly as is desirable without freezing a portion of it?

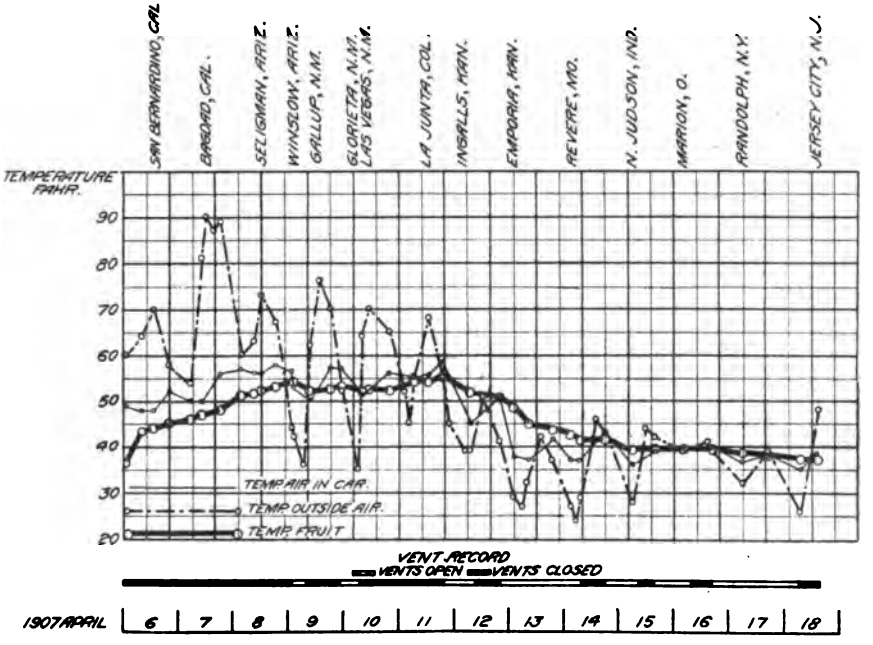

FIGURE 11.—Diagram showing the temperature record of a carload of oranges, precooled and shipped without icing under regulated ventilation, April, 1907. Even with ventilators closed the temperature of the fruit rose rather rapidly during the hot weather prevailing during the first part of the trip, but fell again as the weather became colder in the latter part of the trip.

Or is it feasible to develop a system of handling which will admit of cooling the oranges before packing and at the same time forestall the anticipated objections of employees to working in low temperatures in packing in order to avoid condensation on the fruit? Machines for the wrapping of the fruit as it comes from the cold rooms and so preventing condensation have been suggested as a possible solution of this feature of the problem.

Some of these questions have been presented before, but are still at least incompletely answered. To obtain data bearing on some phases of the problem the Department of Agriculture during the past season fitted up an experimental precooling plant as an auxiliary to a large ice and cold storage plant at Los Angeles, Cal.

In this plant, which was of the car-cooling type, air ducts and fans capable of handling large quantities of air were connected to the bunker room of the cold storage plant and carried to a siding where connection could be made to the ventilators at either end of a loaded fruit car. The capacity of the bunker room was sufficient to insure a supply of air at a low temperature. Valves for regulating and quickly reversing the air current through the car were provided. Provision was also made for the measurement of air temperatures, pressures and velocities in the ducts. During the cooling process the air and fruit temperatures were also observed at numerous points in the car, specially constructed thermometers being used for obtaining temperatures of fruit at the centres of the packages, where the cooling was found to be far less rapid than in the outer portions of the same packages.

With this plant it has been found entirely possible to cool fruit in this manner, but the time required is considerable—from fifteen to twenty hours being necessary to reduce the average temperature sufficiently to check the development of the destructive mould. The cooling was in all cases extremely unequal in different parts of the car, so that in order to reduce sufficiently the average temperature it was necessary to chill some of the fruit to the danger point, fruit temperatures below 30° being frequently observed. It appeared that a more rapid circulation of air at a relatively higher temperature was more effective in reaching the fruit at the centres of the packages without undue chilling of the more exposed fruit, and as a result the average temperature could be rather more rapidly lowered than with a less rapid circulation of air at a lower temperature. It was also found to be of distinct advantage to reverse frequently the direction of the air current through the car, not only as a means of obtaining less inequality in temperature, but the average cooling appeared to be somewhat hastened. Contrary to expectation the loss of refrigeration from the car during the process does not appear to be very serious, although very low air temperatures were sometimes observed in the cars. Exact statements cannot very well be made at the present time, as the data have not as yet been thoroughly worked over, but the results will be more fully stated in a bulletin on precooling to be issued shortly by the Department of Agriculture.

As a commercial test by private shippers, about forty carloads of fruit were precooled in a large ice storage room cooled by brine piping. Some of this fruit was utilized for tests by the Agricultural Department and the results are included as a part of those already

stated. The cooling of fruit under such conditions was watched with some care and was found to be less rapid than might be expected. No forced air circulation was used in these rooms, but the conditions were quite favorable for good gravity circulation, the rooms being very high and provided with a fair amount of pipe surface on the walls. The packed fruit was stacked to a little over one-third the height of the room. It was found that several days were necessary to chill effectually the fruit at the centres of the packages.

The interest taken in precooling may be estimated from the fact that both the large railroad systems entering California have erected small experimental plants with an evident view of determining the practicability of the central precooling station. The Santa Fé Railroad interests have erected a plant of the warehouse type, to which the fruit is brought and unloaded for cooling. This plant has a capacity of six or eight carloads and is provided with an air circulation system. Quite a number of cars of fruit were cooled experimentally, but the results of the test have not been made public. It is understood that the rate of cooling was somewhat less than that realized in the tests conducted at Los Angeles by the Department of Agriculture. That the results were, on the whole, satisfactory is inferred from the fact that press reports from California announce that a large plant of the same general type is to be erected. These reports are not as yet otherwise confirmed.

The Southern Pacific Railroad system has erected in central California a plant of the car-cooling type. This plant is arranged to cool one car at a time by circulating cold air through the car. It was completed too late in the season to be used for extended experiments. A few tests have been conducted at this plant by the Department of Agriculture in the precooling of grapes. While the results are incomplete, it may be stated that the cooling was rather less rapid and more unequal than was anticipated, the cooling of the grapes at the centres of the packages being unexpectedly difficult.

In conclusion, it is desired to express an appreciation of the co-operation extended the Department of Agriculture, especially by certain of the refrigerating interests in southern California, who have made it possible to carry out these experiments in precooling, which, it is hoped, may ultimately prove of some value to those concerned.

DISCUSSION.

Louis Block.—I would like to ask Mr. Dennis whether there is any explanation as to why the mechanically injured fruit decays more rapidly than the other.

S. J. Dennis.—The reason is that it increases the chances of inoculation by mould spores.

Louis Block.—The opportunities for attack are increased?

S. J. Dennis.—The mould spores float around the packing houses in more or less abundance, and mechanical injury in the skin of the orange gives those spores a chance to grow.

Louis Block.—Will they adhere more easily to mechanically injured portions of the fruit than to the perfect portions?

S. J. Dennis.—Perhaps I have not made the point clear. Even if the mould spores are on the skin, they will not grow unless the tissues have been broken by some kind of injury. As the results of our tests it appears that the only chance for the mould to grow is found where there is a mechanical injury in the skin. If there is none the mould spores do not enter.

Louis Block.—Then the perfect fruit would last forever?

S. J. Dennis.—Not forever.

Louis Block.—The mould spores will eventually take hold of the fruit?

S. J. Dennis.—No; there is one point which I have not touched upon, which is brought out in the publications of the Department of Agriculture. A fruit, either on or off the tree, will go through certain natural chemical processes in ripening. When the fruit is cut from the tree the processes take place more rapidly and finally result in the breaking down of the fruit by old age.

Louis Block.—Even if it is kept in cold storage?

S. J. Dennis.—No matter how it is kept. The cooler temperature simply retards the ripening process.

Louis Block.—I am trying to explain to myself why precooling will preserve the fruit much longer. The fruit is cooled to 32° Fahr. and then brought up to 60°, after which it is brought down to 40°, and that seems to preserve it longer than if it was not previously precooled. It has undergone changes and I was wondering whether those changes were not beneficial in that they destroy the mould spores, or whatever it is that brings about the decay, and only because the change of temperature has taken place.

S. J. Dennis.—I do not think that is the case.

Louis Block.—If you took a box of oranges and put it in cold storage for a week, then took it out and set it in this room for another week, placed it in cold storage for a week and again put it in this room for a week, and then in cold storage, would it not last longer than a fruit which is put directly into a cold storage room?

S. J. Dennis.—From the results of the investigations of the Agricultural Department I should say no.

Louis Block.—Have such experiments been made?

S. J. Dennis.—Not exactly like the hypothetical one, but it has been pretty well demonstrated that the moulds do not develop, or at least develop very slowly, at low temperatures, especially in the first stages. That is, take an orange, with the mould spores already in it; keep that orange cold all the time and the mould spores will develop very slowly, much more so than if the fruit remains at a higher temperature. If you allow the fruit to remain at the higher temperature the mould has a better chance to develop.

Louis Block.—There are, no doubt, different mould spores, some that will grow in low temperature and some in high.

S. J. Dennis.—The only mould which appears to be very important in the case of the orange is the blue mould.

Louis Block.—That grows best in one temperature.

S. J. Dennis.—In relatively high temperatures.

Louis Block.—Is the other mould which you find on the orange, although it is in cold storage, of the same nature?

S. J. Dennis.—No; the orange will finally go down by itself without any infection by moulds, just as will an animal, of old age.

Louis Block.—Does that apply to apples as well?

S. J. Dennis.—It does.

W. E. Parsons.—Do I understand that after you have precooled the fruit the temperature does not rise much, if any, above the temperature of the refrigerator car?

S. J. Dennis.—I mentioned one instance which, without explanation, I think is misleading—one temperature of precooled fruit where the temperature rose and then fell again. In that particular car, which was loaded very full, the boxes were packed up solidly. There was no chance for air circulation through the car. There was just a little narrow space through the car for the cold air to go through and take up the heat along the sides of the car.

W. E. Parsons.—The idea in precooling is to cool it down and then not let it rise?

S. J. Dennis.—Yes.

Louis Block.—Why is it called "precooled"?

S. J. Dennis.—Because the fruit is cooled before shipment.

John A. Ruddick.—Mr. Chairman, Mr. Dennis has given us a very interesting paper on a question in which I am considerably interested, and I would like to ask him how he obtained the temperature records in the cars during the trip.

S. J. Dennis.—The cars were locked with padlocks and were sent in the care of a messenger. The duty of the messenger was to enter the car as often as possible. At every stop, either accidental or otherwise, he entered the cars and took the temperature as rapidly as possible.

John A. Ruddick.—Do you think there is any difficulty in getting accurate temperature records of a car after opening the door, as I suppose the attendant opened the door of the car?

S. J. Dennis.—I have watched that closely myself. After entering the car and shutting off the cooled space, the car remaining stationary for some moments and with its temperature very much below that of the outside air, keeping myself personally as far away from the thermometer as possible and watching it while somebody else entered, I found that it was not very quick to change.

John A. Ruddick.—Was the thermometer carried all the time?

S. J. Dennis.—Yes; it was there all the time. That is an important feature in any temperature test.

John A. Ruddick.—Have you tried the recording thermometer for that purpose?

S. J. Dennis.—Yes.

John A. Ruddick.—In the cars?

S. J. Dennis.—Yes.

John A. Ruddick.—Do you find them satisfactory?

S. J. Dennis.—Owing to the vibration we find some trouble in getting a record.

John A. Ruddick.—What kind of a thermometer did you use?

S. J. Dennis.—The Richard thermometer.

John A. Ruddick.—That is the French thermometer?

S. J. Dennis.—Yes; it is the finest instrument, but it is a little too sensitive for car work.

John A. Ruddick.—Did you endeavor, by tracing the record of the thermograph, to determine the length of time a car was detained at different points? We have found that rather useful. When a thermograph is placed in a car and the latter is put in motion the vibration is recorded, and when the car is standing still the record is in a straight line. We were able to check up the railroads very well by thus finding out how long a car had been standing still at any given point.

H. D. Stratton.—I understand the Illinois Central Railroad has cooling sheds for bananas.

S. J. Dennis.—I think those sheds are owned by the "Frisco" Railroad system and operated by the United Fruit Company. They

are provided with a refrigerating plant and air-circulating systems, very similar to the car-cooling plants used in precooling experiments in California. Bananas will stand only a moderately low temperature, say 50°; no attempt is made to cool the fruit below 50°, as it spoils it, and the question of insulation is rather different.

C. H. Brownell.—I would ask Mr. Dennis one question in regard to how the packages are distributed in the room; have they covers on and are they piled one on the other?

S. J. Dennis.—In this particular case the fruit was in packages and was placed in rooms about 10 feet high; the temperatures were taken at all points that were exposed with the fruit right in place.

C. H. Brownell.—The package was closed?

S. J. Dennis.—The package was exactly as it was shipped.

C. H. Brownell.—We have found in the precooling of poultry that by leaving the lid off a package and by piling the packages so that one will be 2 or 3 inches above the others—we use trucks with temporary shelves for that purpose—we are enabled to kill poultry until 12 o'clock noon and ship at 6 o'clock the same evening. In other words, taking poultry at the temperature of the bird, animal heat, and leaving the lid off the package and watching the circulation, the package can be shipped in six hours, and the bird be in perfect condition. If you would experiment on that line, it might work the same with the oranges.

S. J. Dennis.—We did that to some extent; the boxes were fitted with cleats which separated them by an inch and a quarter, or something like that, and I suppose 3 or 4 inches of space was left between each row of boxes.

C. H. Brownell.—We left the top of the package off also.

S. J. Dennis.—You are familiar with the orange package that has a number of openings in it?

C. H. Brownell.—Yes, but you would gain more by leaving the top off.

S. J. Dennis.—We would undoubtedly gain something.

Gardner T. Voorhees.—I would like to ask Mr. Dennis the minimum safe temperature for carrying the orange?

S. J. Dennis.—I have not determined that; I have had some as low as 26°.

Gardner T. Voorhees.—And have had no trouble?

S. J. Dennis.—I do not want to say that, but I have found thermometers cooled down to that temperature at certain points in some cars cooled, and the cars as a whole would be reported in fine condition on arrival at New York and the fruit brought high prices there.

Gardner T. Voorhees.—Twenty-six degrees?

S. J. Dennis.—Yes. I cannot be quoted as saying that that is a safe temperature, but I know I have seen fruit cooled as low as that in some of the cars handled, apparently without appreciable harm.

Gardner T. Voorhees.—In the package?

S. J. Dennis.—In the fruit itself, the thermometer being inserted in the fruit; the air temperature of that car was about 17°.

F. E. Matthews.—Have any experiments been made to kill the mould spores?

S. J. Dennis.—So far as I know no such experiments have been conducted.

F. E. Matthews.—Why I asked that question is because in dealing with some of the bacteria encountered in meats, for instance, what are called the "sour" germs in the curing of hams, it has been found difficult to kill them. In the cold temperatures they simply lie dormant, and go to work again when the temperature rises.

H. W. Tinker.—Are the mould spores killed by the low temperatures?

S. J. Dennis.—Only a small amount is killed by any such temperature as that.

H. W. Tinker.—Was any of this precooled fruit held in cold storage after arrival?

S. J. Dennis.—No.

Chairman Starr.—I would like to ask if the Department of Agriculture has ever experimented with air that has been passed over what we call open calcium brine. According to some German authorities calcium brine is a germicide and it is being used more in this country than it has been. I do not know whether your experience has included anything of that kind.

S. J. Dennis.—Nothing of the sort, to my knowledge, has been done in the Department of Agriculture.

Chairman Starr.—No attempt has been made to eliminate or to kill the spores, except by the use of temperatures?

S. J. Dennis.—We are not trying to kill them, but rather to check their growth. It does not appear to be possible to kill them. You will kill the orange before you will kill the spores, and as for protecting the orange with any germicide, unless you could charge the air very heavily with it, I do not think you could do much, because after the fruit is packed the spores which do the damage are those already on the fruit and not those in the air; and after the

spores are on the skin of the fruit it is a question of keeping the latter as cool as possible, rather than anything else.

Chairman Starr.—I thought I understood you to say that the spores were in the air.

S. J. Dennis.—In the packing houses, where there is more or less rotten fruit, the spores are blown about and lodge on the fruit before it is wrapped.

Chairman Starr.—Derived from the fruit originally?

S. J. Dennis.—They come from the growth of mould on rotten or decaying oranges, or on other decaying vegetable matter.

No. 41.

THE AUTOMATIC REFRIGERATING MACHINE.

By Van Rensselaer H. Greene, New York, N. Y.

(Junior Member of the Society.)

In the refrigerating field, where large cold storage houses are fighting the large ice companies for a monopoly of trade, the small refrigerating plant has a hard struggle for existence. If the small plant is to be approved commercially and adopted by the retail tradesman, it must be capable of displaying at all times and under all circumstances economy of space, labor and cost. At present there are on the market hundreds of refrigerating machines which fulfill the small space requirements, but which fail to reduce labor and cost of maintenance. Since, however, the successful machine must meet not only the first conditions, but also the second and third conditions, the process of elimination leaves only the automatic refrigerating machine.

The word automatic means self-regulating, and in its truest meaning is applicable to the type under discussion. The automatic refrigerating machine is guaranteed to maintain a properly insulated compartment at a temperature which shall not vary more than two degrees either up or down from the desired point, or, in other words, a range of 4° Fahr. The automatic compressor is in some respects similar to the other enclosed types with truncated pistons, in which the suction valves are located. The discharge valves are in the head. The suction valve is gas-cushioned, and the machine is built in such a careful manner as to make possible a comparative displacement efficiency which will easily average 90 per cent. instead of the customary 60 per cent. to 75 per cent. There are always two single-acting cylinders; the cranks are set 180° apart.

The two automatic valves and other devices used in connection with the high pressure and the low pressure sides of the system are as follows: Connected with the high pressure side are the water-regulating valve and the high pressure cut-off. The water regulator contains a diaphragm acted upon by a spring on one side and the condensing pressure on the other. With this diaphragm is connected a plunger which opens and closes the water valve directly below. When there is any increase in pressure on the condenser the greater

pressure on the under side of the diaphragm allows more water to flow to the condenser. A diminution of pressure produces the reverse result. When the pressure drops several pounds, as per example, when the machine stops operating, the valve completely interrupts the water supply.

The high pressure cut-off is an electric switch operated by pressure. Should the head pressure exceed a predetermined maximum, because of failure of water supply or other deficiencies common in daily experience, this little switch acts directly on the motor controller and stops the machine.

In operation, on the low pressure side is the automatic expansion valve, which, like the water-regulating device, consists of a spring acting upon a diaphragm against the ammonia back pressure. This valve is constructed with a diaphragm of extra large area, as well as a spring of great size, so as to be affected by any slight increase or decrease in the back pressure. After the compressor has been shut down the increase in the back pressure caused by the feeding of the expansion valve brings about an increase in pressure which in time shuts off the flow of ammonia. With a reverse movement, when there is no feed in the expansion valve, and the compressor has again started, the expansion valve causes the spring to continue its regulated feed until the compressor is again shut down.

We will next consider the question of stopping and starting the compressor. This is accomplished by placing in a box a laminated thermostat, made by mounting together two substances of widely dissimilar coefficients of expansion. Where used in connection with alternating current the thermostat is joined with a solenoid, which, when energized, throws the motor directly across the line. This type of starter is employed in connection with motors of as large a horse power as the central lighting stations will allow thrown directly across the line. When the motor is too large for such a starter a rheostat type of starter is employed and operated by hydraulic power, the flow of water being regulated by the starting solenoid.

In the case of direct current the thermostat is connected with a solenoid, which when energized makes contact with another solenoid, which in turn cuts out a series of resistances, thus increasing the potential impressed upon the motor. In all cases, when contact on the stopping side of the thermostat is made by the thermostatic blade, the starting solenoid is short circuited, and accordingly loses its magnetism. Then the arm drops and the line to the main solenoid is broken, so that the rheostat arm falls to its original starting position.

So much for the construction and general operating principles of this machine. Let us now turn to what is more interesting to the designing engineer—the method of piping.

Automatic expansion valves of the pressure-reducing type, which has been found to be the only reliable valve so far produced, cannot be made to operate in parallel. Hence the several cold storage boxes of an automatic plant are piped in series, the amount of pipe in each box being proportioned to the duty performed. Every running foot of pipe is thus utilized to its best advantage, but it is obvious that the radiating surface in the expansion coils must be more accurately proportioned to the duty required than can possibly be done on the cubic foot ratio basis. This problem is handled by first determining the number of square feet of heat-absorbing wall area, estimating its heat conductivity, which, together with the difference in temperature within the inside and outside of the wall, will enable the heat absorption in British thermal units per twenty-four hours to be accurately determined. This added to the "product duty" gives the total amount of heat which must be removed from each cold storage box. The back pressure and the temperature of the ammonia corresponding are determined by the temperature of the coldest box in the series, after which the number of square feet of heat-absorbing surface in each cooler is found, due consideration being given to the difference in temperature between the ammonia and the atmosphere of the respective cold storage rooms.

The amount of pipe to be placed in each room evidently depends on the relative difference in temperature, and is determined by balancing up the first cost of the pipe required to operate a high back pressure against the loss in efficiency owing to the low back pressure, due consideration being given to weather conditions. The majority of boxes have a narrow or wide range in difference of temperatures.

The best proof of the effectiveness of this arrangement is that as many as eleven boxes of as many different temperatures have been refrigerated by a single automatic system, controlled by a single thermostat, the expansion coils being fed by a single automatic expansion valve. The advantage of this arrangement can readily be understood when it is remembered that in order to regulate the temperatures of a non-automatic system the refrigerating engineer throttles his expansion valve, thereby reducing the back pressure and virtually regulating his temperatures by reducing the efficiency of the whole refrigerating system.

In the automatic system the piping is already correctly proportioned to the amount of duty, so that there is no throttling necessary.

A constant high back pressure, and accordingly maximum efficiency, is always maintained, so that when the temperatures have been sufficiently reduced to allow it, the system, instead of becoming less efficient, suspends operation and saves both power and water bills for as long a time as the temperatures will permit. As soon as the temperatures have risen a predetermined number of degrees the plant again operates.

The effectiveness of this method of control is best indicated by Fig. 1, which shows the relative time in which a 5-ton completely automatic machine was in operation. The whole question of being able to produce the most satisfactory results is to estimate the duty and arrange the pipe of the several boxes with sufficient accuracy. This has been found to be much more easy to carry out in practice than would at first be suspected.

When the problem of ice making comes up it is handled in the same manner as if it were the refrigerating box by using an exceptionally heavy class of insulation and figuring the duty as 1.6 times the refrigerating duty. The best results are obtained by placing the ice box nearest the expansion valves, followed by the boxes to be cooled. This method practically insures a flooded coil system in the ice-making tank, and keeps the brine at an almost uniform temperature under all conditions.

The thermostat is located in the box most suitable for the purpose, usually the last in the series. The reason is obvious. If the last box is cooled to the desired temperature and has shut down the compressor, the other boxes must be at the desired temperature because the box under the thermostatic control will not act upon the thermostat until the entire coil surface is frosted. A certain length of time is therefore required for the ammonia to expand from the expansion valve throughout all the pipe up to the thermostat in the last box. This duration of time is always sufficient to bring all the other boxes to their desired temperatures before the machine shuts down. If we bear in mind that all the boxes are piped on a given degree difference between the room and the gas temperature, it is easy to see the effect on the box which is hard worked and not under thermostatic control. Should this box increase in temperature 10° or so from the desired point, it will proportionately increase the degree difference between the pipe surface and room temperature, which is equivalent to increasing the pipe ratio. As the box temperature decreases the piping ratio decreases until that temperature for which the box was designed is reached, when normal conditions prevail.

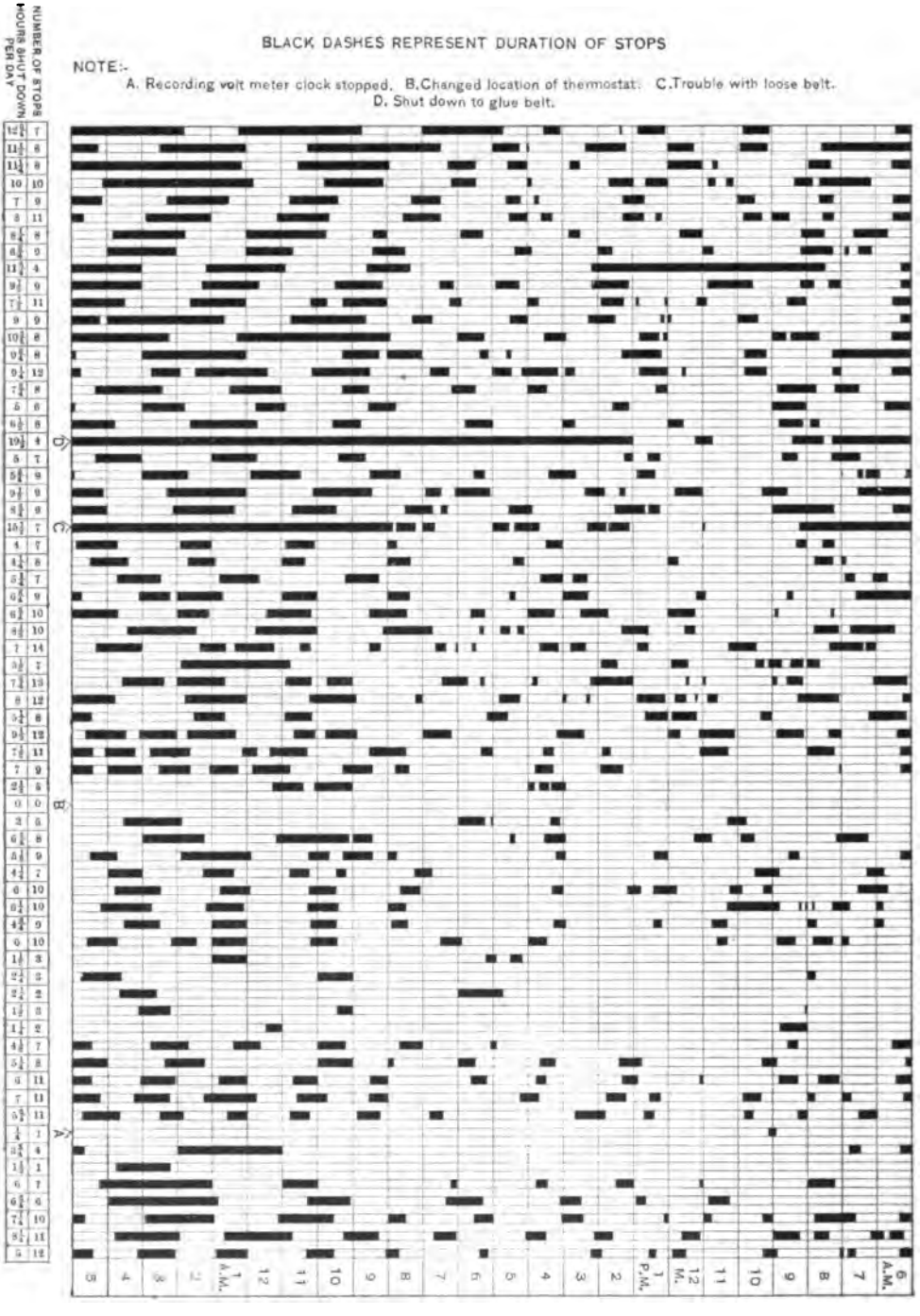

FIGURE 1.—DIAGRAM SHOWING PERIODS OF OPERATION OF A 5-TON AUTOMATIC REFRIGERATING PLANT FROM JULY 11 TO SEPTEMBER 14, 1906.

When the mechanical features have been fully considered, the next subject of interest bears on the utility and economy of the machine. At last year's meeting of this Society one of our esteemed members, an advocate of the Linde wet compression system, spoke of the great advantage of the wet compression system. The placing of the hand, he said, on the discharge pipe of the compressor would show to the experienced operator the condition of the gas on its way to the condenser. In answer, the advocates of the dry compression system produced data indicating that less power per ton was required with the latter than with the former, and also that the latter system was producing a considerably higher efficiency. It seems to the writer that both of these advantages are present in the automatic machine. What could be more sensitive than a delicate thermostat, holding its hand, as it were, on the suction pipe to the compressor, allowing the gas to become superheated only at the compressor itself, and then only to a slight degree! Then again, as in the dry system, no gas in a wet condition ever enters the compressor proper. The builders of the automatic machines are therefore able to avail themselves of the advantages of minimum clearance between cylinder head and piston and of many other points consistent with high efficiency. Because of the automatic features, the standard of utility and economy can never be lowered. The highest possible back pressure for a given room temperature is once and for all determined by an experienced engineer, and no operating engineer, either by carelessness or ignorance, is allowed to spend his employer's profits by over-consumption of electric power or coal. Moreover, it is an established fact that boxes may be so piped on the cubic-foot basis as to sometimes produce most inefficient results. Many instances can be cited when two rooms were cooled by the same machine, in one of which was too little piping and in the other too much, though the piping for both was figured on a basis of 15 to 1. In order to hold these rooms, the back pressure was reduced for the sake of the room poorly piped, while the other room with too much piping added friction to the passage of the gas and a slight degree of superheat, with the result that the system often suffered a considerable loss of efficiency. Such conditions are impossible in automatic plants.

When we have finished a review of a mechanical producer, we have not said the last word until we have considered the operating costs. The data for the diagram were obtained from Bristol recording voltmeter charts, Fig. 2, which record the number and duration of "shutdowns" of a 5-ton completely automatic plant in the Heublein Hotel at Hartford, Conn. An examination of these charts

will show that while the duration of each "shutdown" was not in itself long, a great many took place during the twenty-four hours. The total number of hours during which the machine rested bears to the number of hours in a day the relation of 6 to 24, or, in other words, the compressor operated for only about 75 per cent. of the total time. The saving in the cost of electricity is about 20 per cent. of what

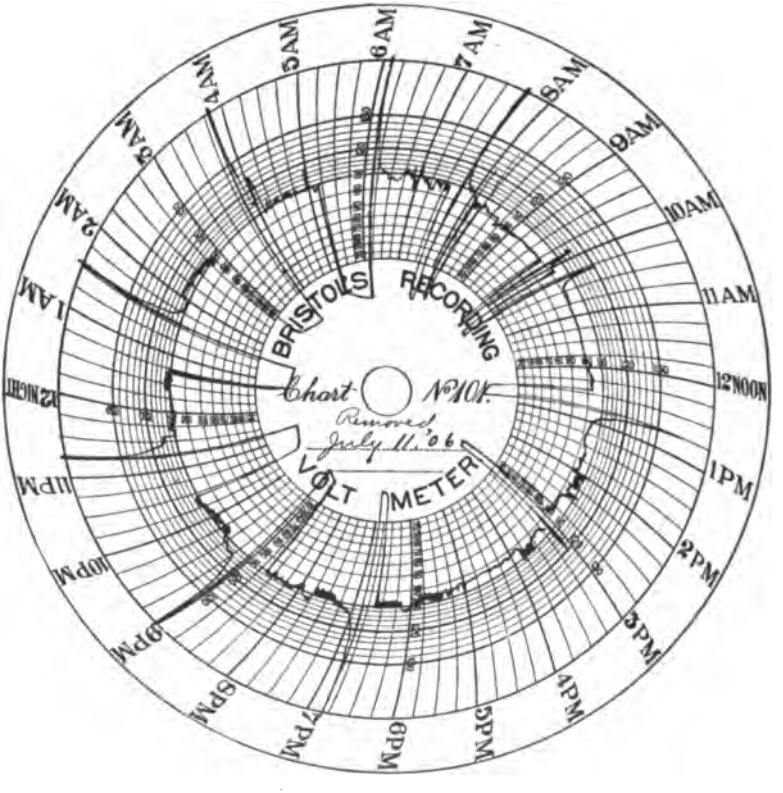

FIGURE 2.—RECORDING VOLTMETER DIAGRAM, SHOWING PERIODS OF OPERATION OF A 5-TON AUTOMATIC REFRIGERATING PLANT FOR TWENTY-FOUR HOURS.

the cost would be based on a twenty-four-hour run, and 25 per cent. of the water bill is also saved.

Finally, through the wipe system of crank and connecting rod lubrication and the unusually large ring oilers in the outboard bearing, the entire outfit becomes very nearly foolproof. Since general cleaning and slight attention to the commutator and stuffing box are the only requirements, there is no need for skilled attendance. In all

instances the work can be accomplished by the handy man in the day time. Generally a non-automatic machine must be shut down at night and the process of refrigeration continued by brine; but as this inherent inefficiency of the brine system necessitates a machine more than twice the normal size on account of the shorter hours, the cost of installation is practically doubled.

There is working to-day in one of our city restaurants active proof of these assertions. At the time of the strike among ice drivers last summer this machine not only cooled the boxes but supplied other restaurants with ice. It is stationed in a corner of the cellar, where it works unattended day and night without any but legitimate cessation.

DISCUSSION.

Louis Block.—Where is the thermostat placed?

V. R. H. Greene.—In the last box, near the last run of pipe going to the compressor.

Louis Block.—Then all the coils are connected in series?

V. R. H. Greene.—Yes.

Thomas Shipley.—Suppose your No. 5 box should require more cold than you have figured it will, what will happen?

V. R. H. Greene.—Nothing, until the machine starts, and then the increased difference in temperature between the ammonia and the atmosphere, brought about by the increased duty, will cause the expansion piping to be more effective and soon reduce the box to the required temperature.

Thomas Shipley.—Without any relation to the box at all?

V. R. H. Greene.—Yes.

Thomas Shipley.—You say that by having only one expansion valve you get the back pressure as high as possible?

V. R. H. Greene.—Yes; the number of square feet of pipe surface in each box is figured on the basis of the highest practicable back pressure, which has been previously determined.

Thomas Shipley.—You say that that is the way to get the highest back pressure?

V. R. H. Greene.—Yes, because the automatic valve can be set at any pressure required to produce the desired temperature.

Thomas Shipley.—You do not know what the temperature is at the other end of the coil?

V. R. H. Greene.—I do not care. I know my back pressure is a constant; it never fluctuates.

Thomas Shipley.—How do you know that?

V. R. H. Greene.—Because there is practically no friction.

Thomas Shipley.—No friction?

V. R. H. Greene.—Only a very slight amount.

Thomas Shipley.—Have you investigated that?

V. R. H. Greene.—Yes; we have made some tests. We use a very low velocity—39 to 40 feet per second.

Thomas Shipley.—How do you regulate the velocity?

V. R. H. Greene.—The velocity of the gas? We increase the size of the pipe so as to allow a low velocity at an increased cross-section.

Thomas Shipley.—You have nothing to do with the velocity. How are you going to regulate the velocity of the gas going through the pipe when you are controlling the operation of the system by the temperature of the gas going to the compressor?

V. R. H. Greene.—You have a given amount of duty to be performed.

Thomas Shipley.—But that duty is not constant.

V. R. H. Greene.—Practically so. If it is not so the machine shuts down.

Thomas Shipley.—The duty might be very much heavier than you estimate. Do you not know that at about noon, when those boxes are being used in hotels and restaurants, the duty is ten to fifteen times greater than at other times?

V. R. H. Greene.—Suppose it is; it is for this duty that the plant is designed.

Thomas Shipley.—The machine drives more gas through, is that it?

V. R. H. Greene.—Yes.

Thomas Shipley.—You would then have more gas in the pipes.

V. R. H. Greene.—Yes.

Thomas Shipley.—If your pipes contain more gas, then they hold less liquid and are less effective.

V. R. H. Greene.—Temporarily, yes.

Thomas Shipley.—You have assumed a certain amount of work to be done in a box, and have put in sufficient pipe surface to do that work under certain conditions. If the work in the box is doubled or trebled the temperature in it will go up, which will increase the evaporation of the liquid in the pipes, generating more gas, and by cutting down the liquid surface in the pipes make them less efficient, unless more liquid is immediately fed to the coils. This you cannot do when the coils are connected as you describe. If you will experiment you will, no doubt, find that in a series connection, when one box is called upon to do an extra amount of work, the gas formed

in the pipes in that box will drive enough liquid out of the coils in that box to make them considerably less effective than you have figured them to be, and very likely the same rush of gas will drive the liquid out of several other boxes, thus affecting the whole system. You will also find, even in ordinary operation, that the pressure at the liquid end of your series of coils is considerably higher than where it enters the machine.

V. R. H. Greene.—There must be a difference between the two, but I do not see how it can be excessive, because it is not a natural conclusion that all the boxes are working at the same time.

Thomas Shipley.—If you test them out you will find the difference.

V. R. H. Greene.—I grant that there is a difference, but all boxes cannot be working equally hard at the same time, and therefore the difference will not amount to very much.

Thomas Shipley.—In a restaurant at noon everybody is in a hurry, and the boxes are in use all the time.

V. R. H. Greene.—Yes, they are being constantly opened.

Thomas Shipley.—You say that your machine is of the trunk type—by that I mean the enclosed crank type—and you get 90 per cent. efficiency.

V. R. H. Greene.—I realize that I should have been more explicit regarding what I meant by efficiency. When I wrote my paper we had no exact tests on the absolute displacement efficiency of these machines; consequently we arrived at a relative displacement efficiency by testing a number of machines and noting their relative displacement efficiencies. Since then we have made a number of tests for absolute displacement efficiency by weighing the ammonia, and they have checked up to show that 72 per cent. absolute displacement efficiency corresponds to the 90 per cent. relative efficiency.

Thomas Shipley.—There is a big difference between 72 and 90 per cent.

V. R. H. Greene.—Yes. In determining the relative displacement efficiency we took a number of machines of our own make, as well as other makes, and discharged them singly into a tank of known capacity, and computed the displacement efficiency from the theoretical and actual displacement required to produce a given pressure in the tank. With those results we are trying to make a machine that does not leak by the piston and valves quite as much as some of the others. It is a small machine, built up to only 10 tons refrigerating capacity.

Thomas Shipley.—Do you take your suction through the trunk of the machine?

V. R. H. Greene.—Yes.

Thomas Shipley.—There is a considerable heat in the trunk.

V. R. H. Greene.—Yes, some.

Thomas Shipley.—Doesn't that expand the gas?

V. R. H. Greene.—To a slight degree. We carry our frost line as near the compressor as possible, so as not to allow much superheating.

Thomas Shipley.—Why I make that point is because we have found that the most inefficient type of machine is one in which the suction is brought into the trunk. It comes in contact with all the moving parts, and is materially heated, which causes a considerable loss. In machines of this type which we build we have tried to avoid this loss by bringing the suction into the cylinder of the compressor direct, so as not to allow the gas to enter the trunk case. We have had considerable experience with this type of machine.

V. R. H. Greene.—I do not think I have claimed anything more than would be claimed by builders of large machines. You must remember that our machines are built up to only 8 tons capacity.

Edgar Penney.—The part interesting to me is to know how a man can so exactly determine in advance the necessary piping for a lot of boxes of a given size in a busy restaurant or hotel under conditions that we old-timers had to meet by standing at the door with a club to prevent the cooling of the whole kitchen, or, at least, to keep it closed long enough to cool the box. I suppose Mr. Greene makes his cooling surfaces more than large enough; hence, if there is a tendency for the box to become too cold the machine shuts down, and during the dinner hour, when the cook keeps the door constantly open, the machine runs for all it is worth. This means a machine many times too large for its work, and a very low efficiency of cooling apparatus.

V. R. H. Greene.—I disagree with that statement. In the first place, it is a great deal easier to reach those conditions absolutely than it is to figure out the theoretical conditions in which the boxes are to be operated. Where people buy refrigeration from a pipeline service they do not consider that they have had their money's worth unless the box door is left wide open; but that is not true where a man is interested in cooling his own meat. The average small butcher expects the door of his refrigerator to be closed. He knows pretty well what is going on there.

Edgar Penney.—That puts a little different face on the matter.

You cater only to a certain class of trade, where you can get at the exact conditions, and they are certain to be nearly uniform; but I am speaking of a broader and more useful application. But take ten boxes at differing temperatures in series—I suppose that you consider this going into it on quite an extensive scale—that would bring you into difficulties, would it not?

V. R. H. Greene.—We have piped as many as eleven boxes in series, and the conditions have not been very different from what they would have been had there been only one box. It simply means difference in heat-absorbing areas. We are not trying to cater to any particular line. We will take any line, but in order to figure intelligently we must know the condition under which we are going to operate better than we would if we were simply going to guess at the ratio.

Edgar Penney.—I presume that the greatest part of your experience has been in equipping meat markets.

V. R. H. Greene.—Yes, that is true.

Edgar Penney.—That would be comparatively simple, because the main business is handling cold storage meat. The butcher takes his meat out of the box, closes the door, and puts it on the counter to cut. This makes little or no tax on the machine.

V. R. H. Greene.—The most important line is naturally the meat business, because in that business there is a regular call for small refrigerating plants.

Edgar Penney.—I think you would encounter difficulties if you undertook to cool a large and busy restaurant at rush meal times.

V. R. H. Greene.—We have a number of machines running in restaurants in New York now. I have the figures from the owner of one of these plants. He says that during June, July and August his power and water bill amounted to $70 a month as compared with an ice bill of $130 per month.

Edgar Penney.—You have to make a machine more than big enough to do the work under maximum conditions.

V. R. H. Greene.—The machine runs twenty-four hours per day if necessary. The required twenty-four-hour duty of the machine need be but very little in excess of the maximum duty.

Edgar Penney.—You spoke about your machine running under normal conditions, really having a capacity to perform twice as much or more work, and of operating it twenty-four hours daily intermittently. I can scarcely distinguish any difference in economy, convenience or safety of performance between running a machine on the ordinary plan—ten hours or less per day—and then, after the

rush is over, shutting the plant down for the night, and starting it again in the morning. There would then be no machinery to worry about when the owner should be asleep.

V. R. H. Greene.—That is the usual practice, and the temperatures in boxes vary 3° or 4°, sometimes 10°, in a night.

F. E. Matthews.—The example that Mr. Penney cites might apply in the case of butchers' boxes, where the doors are closed during the night, but in the case cited by Mr. Greene the ten or twelve boxes are used up to 12 o'clock at night, and again beginning at 5 o'clock in the morning. Mr. Penney's method would not give very uniform temperatures.

Edgar Penney.—Generally the cut meats come from the large storage rooms. Nearly all the hotels have large reserve storage rooms, but the boxes I mean are the small ones for the cook and the baker, the grill box and oyster counter, etc. Their contents are drawn from the general supply cold room, and are consequently precooled. It is these small boxes that we are trying to keep cool. It is a great advantage to have a well-frosted solid wall of cooling pipe across the back and ends, or in certain cases to have a brine tank in the box to act as a reservoir to maintain regular temperature when the machine is shut down for the night. The large icy coil surface cools the box, even though the door is open, by direct radiation, the contents of the box being almost in contact with frost. When there is a machine big enough, even when the door is open, frost will be maintained on the coils. It is a very difficult problem, as you know if you have had experience in attempting to refrigerate all kinds of hotel boxes. In a hot kitchen the problem is a big one, but it is refreshing to think it has been so scientifically figured out.

L. H. Jenks.—Mr. Greene, when this automatic device sticks, who starts it up?

V. R. H. Greene.—I do not see any reason why it should stick. Automatic starters are generally employed. For example, the underwriters require sprinkler systems in certain classes of buildings in order to enable them to give a low rate of insurance. These systems are either fed from gravity tanks on the roof, as in the "wet" system, or by a direct outside pressure, as in the case of the "dry" system. In the former case the height of the water in the tank, and in the latter the air pressure in the "dry pipe" operating a float and a diaphragm, respectively, make and break electrical connections which start the motors driving the pumps exactly as thermostats start the motors driving compressors. You must grant that these systems are fairly reliable. The same form of automatic starter is

employed in air-brake systems on electric trains. The air pressure in the air-storage tanks is maintained practically constant in the same way. When you stop to consider these examples it is not as difficult or as unreasonable as you might think.

Thomas Shipley.—While Mr. Greene is talking about the sprinkler system or the air brake, I have to say that if anyone can show me how I can keep the air in the pipes at our factory by means of thermostatic outfits I shall look upon him as a friend. We have had so many freeze-ups with automatic rigs that I have lost faith in them, even those recommended by the underwriters.

V. R. H. Greene.—The reason is that in the automatic sprinkling system the risers stand full of water, because the dry valves are very hard to keep tight. I have had the same experience. In cold storage warehouse sprinkler systems you must have a balance of air on both sides; but that has nothing to do with the question of being able to maintain automatically a constant water level in the pressure tank on the roof.

Louis Block.—Mr. Penney remarked that in the middle of the day, or when hot supplies or hot meats are placed in the boxes, the refrigerating work is naturally increased. Does the thermostat then take care of the machine?

V. R. H. Greene.—So long as the temperature is high the thermostat will not shut the machine down.

Louis Block.—Does your suction pressure increase?

V. R. H. Greene.—No; the expansion valve maintains a constant back pressure. Of course if the boxes get too high you have to take time to cool them down. The amount of work the machine will do is fixed; it operates at a constant speed and at a constant back pressure.

Louis Block.—The thermostat in the return pipe simply determines the quantity of ammonia which is allowed to enter?

V. R. H. Greene.—No; it determines the temperature of a certain box. When the temperature of the box has been reduced to a given point the thermostat makes an electrical contact and stops the machine, and the rise of back pressure shuts off the expansion valve.

Henry Vogt.—How long have you had these systems in use?

V. R. H. Greene.—About three years.

F. E. Matthews.—As to the degree of accuracy with which the operation of the machine can be regulated, I might say that, taking the last coil next to the thermostat, for example, which usually extends about four pipes beyond the thermostat, I have seen the thickness of the ice on that coil vary from 3 inches down to nothing

between the third and the second pipe above the thermostat. In the case I have in mind the thermostat was of the Bristol indicating type, in which the end was placed through the wall, with the end within about 1½ or 2 inches of the expansion coil.

Louis Block.—The temperature of the return pipe determines the quantity of ammonia?

V. R. H. Greene.—No; the temperature of the air at a particular point determines whether the machine shall operate or not.

Louis Block.—The temperature surrounding the pipe close to the machine?

V. R. H. Greene.—Yes; the temperature at the thermostat located near the last coil in the last box in the series.

Louis Block.—The increase of temperature in the box starts your machine?

V. R. H. Greene.—Yes; a rise of one or two degrees causes the thermostat to make a second contact, which starts the machine.

W. E. Parsons.—Are there two thermostats or one in the last room?

V. R. H. Greene.—Just one thermostat, with a high and a low temperature contact.

W. E. Parsons.—That thermostat is connected to the expansion pipe?

V. R. H. Greene.—No; it is located near the expansion pipe.

W. E. Parsons.—Just in the air?

V. R. H. Greene.—Yes.

W. E. Parsons.—That regulates the expansion valve also?

V. R. H. Greene.—No; the thermostat starts or stops the machine as the temperature in the box requires, and when that occurs the increase and decrease in back pressure shuts off and opens the expansion valve.

F. E. Matthews.—The expansion valve is nothing more or less than a pressure-reducing valve, and works just like any other pressure-reducing valve employed on a steam, air or water line.

Chairman Starr.—Will Mr. Greene tell us if, as a matter of experience, he has trouble due to overload on starting the machine?

V. R. H. Greene.—There ought not to be. We have to allow for that in the size of the motor installed. We install a motor of sufficient size to operate under normal conditions from 75 to 85 per cent. full load. With wide belts and not too small pulleys there is then little trouble.

Chairman Starr.—What per cent. load, please?

V. R. H. Greene.—From 75 to 85 per cent. That occasions a

loss in efficiency of about 2 per cent. Taking a motor with a full load efficiency of 90 per cent., it would reduce it to about 88 per cent.

Thomas Shipley.—Will Mr. Greene let us know what he asks from the customer in the way of data, so that he can figure out this pipe so finely?

V. R. H. Greene.—We try to get as much information as possible. The main thing we want to know is the type of insulation.

Thomas Shipley.—No matter how many times the door is open?

V. R. H. Greene.—We have to allow a certain percentage of work for the duty of the box and the door.

Thomas Shipley.—What makes your assumptions more accurate than those of anyone else?

V. R. H. Greene.—If you would get away from the cubic foot ratio basis you would not have so much trouble.

Thomas Shipley.—How do you figure?

V. R. H. Greene.—On the square feet of outside surface, the difference between the room temperature and the refrigerator box temperature, the quality of the insulation and the product to be cooled. Then we put in sufficient pipe to do the work.

Thomas Shipley.—How many square feet of pipe do you put in?

V. R. H. Greene.—Just enough to satisfy the requirements of the calculated duty for product and leakage, and a certain percentage in the thermostat box for regulation—a few feet for the end of the frost line to go and come on.

Thomas Shipley.—You base that on what?

V. R. H. Greene.—What do you mean?

Thomas Shipley.—Some boxes may be used for cooling wine, others are used for meat, others for vegetables, and others for products requiring still different temperatures.

V. R. H. Greene.—Suppose one box is for wine, and we want a temperature of 45°, and the next is for meats, and we want a temperature of 35°—you cannot get any more cold out of the pipe than the surface and difference in temperature between the outside and inside will allow. If the difference in temperature is less we put in more pipe; if greater, less pipe. If the temperature gets away temporarily the difference in temperature is increased and the pipe surface, which cannot change, does more work.

Thomas Shipley.—What is the matter with our doing it the same way?

V. R. H. Greene.—Nothing at all; I only wish that you would.

Thomas Shipley.—Why do you say that?

V. R. H. Greene.—Because there is nothing more unreliable than talking about the number of tons of refrigeration or the number of feet of pipe you must have in a given number of cubic feet of space to be cooled. That does not mean anything. It may be exposed on all sides or on no side.

Thomas Shipley.—When you cannot get the data necessary how are you going to figure closely? People cannot tell you how much they are going to use today, nor that they may not use ten times as much tomorrow.

V. R. H. Greene.—That looks hard on the surface, but fortunately it isn't so hard as it looks.

Thomas Shipley.—I suppose you know that we are installing refrigerating machines, too?

V. R. H. Greene.—Possibly you may not have to handle very small boxes.

Thomas Shipley.—We have handled boxes that a person could scarcely put his head into, and boxes that we could all walk into, and we have learned that it is necessary to pipe up those boxes to suit the duty required from them.

Eugene W. Lewis.—I have had considerable experience in cold storage work, and I want to say that Mr. Greene's statement to the effect that the majority of ice machine companies use the ratio tables and that a room should be piped 15 to 1 is absolutely true. At Chicago we had 1,800,000 cubic feet, and we put in 15 to 1. The compressor was put at 1 to 1; and at Indianapolis it was piped in the same way, and the pipe of the Merchants' Refrigerating Company at Jersey City was worked out along the same lines.

H. N. Borgstedt.—It seems to me that under certain conditions the automatic machine will do a lot of stopping and starting. Has it ever been tried to make this machine of variable speed? Would it not be better to have the speed of the machine vary than to have it stopped and started?

V. R. H. Greene.—I think that would be pretty hard to carry out, because you would have too many unforeseen factors to handle. In some cases we have tried to make the temperature regulate the back pressure by means of a thermostatic expansion valve. Increase in temperature would increase the pressure on a thermostatic liquid acting on a diaphragm, which in turn tends to open the valve, and so increase the back pressure. When the box temperature is high the back pressure is high also. It made a lot of trouble by overloading the motors. I do not see how you can handle the question of

varying speed; I do not see what would be employed as the governing element.

F. E. Matthews.—The question of speed regulation would involve the same trouble as the thermostatic valve. In other words, you would not always be using your motor at full load, and consequently not at its maximum efficiency. You would have to devise some means of field or armature control, with the result that you would not always, and perhaps never, be using your motor at its maximum efficiency. The thermostatic valve works out nicely where there is unlimited power, and tests have been made in which a given amount of work has been done in about two-thirds the time it would take at a constant back pressuure.

Louis Block.—What would happen to the machine should the supply of condenser water stop?

V. R. H. Greene.—Shortage of condenser water increases the head pressure, and that operates a small electric switch which stops the machine in exactly the same way as the thermostat.

Edgar Penney.—Fortunately or unfortunately, aside from your interesting, predigested, theoretical considerations and the application of figured formulas, the commercial aspect of the small refrigerating business is a determining factor. It has been the dream of many engineers to get up a small automatic machine and put it on the market to take care of this supposed long-felt want. I heard one distinguished ice-machine salesman say that if his engineering department would only produce a small machine he could sell 500 a day. His engineering department produced the machine all right, but the selling department soon found the long-felt want did not really exist, and I think this is the problem that confronts Mr. Greene. To my knowledge this machine of his has been on the market for several years, and, however perfect it may be on the basis of efficiency and practicability, there is, of course, a large number of cases in which it might not operate satisfactorily. The whole thing boils itself down—however perfect you may get the machine with his thermostat and automatic feature—to how many you can sell. Of course, it is a nice thing for the electric manufacturing company which builds generators and motors, and for the people who sell electric current.

F. E. Matthews.—I wish to say this, that the company may have expected to get support from the electric companies, but all it ever got did not amount to much.

Theodore Kolischer.—Mr. Greene, has any of your machines ever been operated to produce ice in conjunction with these boxes?

V. R. H. Greene.—Yes; we have one in New York making 600 pounds of ice a day.

Theodore Kolischer.—Has it been necessary to operate the machine twenty-four hours?

V. R. H. Greene.—No, because the ice tank is large, and allowing the ammonia to pass first through this ice box keeps it down considerably, so that when the machine shuts down for periods aggregating three or four hours it affects the temperature but little.

Theodore Kolischer.—I understand you to say that 8 tons is the capacity of your largest machine?

V. R. H. Greene.—Yes, we build machines of from 800 pounds to 8 tons equivalent ice-melting capacity per twenty-four hours.

Theodore Kolischer.—Suppose a hotel desires to make ice up to the utmost capacity of the machine, would it have to run the machine twenty-four hours?

V. R. H. Greene.—Yes.

Theodore Kolischer.—How about the cold storage boxes?

V. R. H. Greene.—If you did not originally plan for twenty-four-hour operation you would have to decrease the amount of piping in the boxes or reduce its refrigerating effect by by-passing some of the return gas.

Theodore Kolischer.—Even with that, how about the regulation of the temperature in the refrigerating box? What I fail to understand is how you can regulate temperatures by operating that automatic machine twenty-four hours when the thermostat regulates it only by starting and stopping. You must operate simultaneously on all the boxes.

V. R. H. Greene.—No; if such a condition came up and we had to run twenty-four hours a day the machine would cease to be automatic as regards the controlling of temperature. There would be no use for the thermostat. We have never made an installation where twenty-four hours' operation in the ice tank was necessary, except in case of special demand, and then the other boxes were by-passed sufficiently not to get too cold.

Theodore Kolischer.—You could not operate twenty-four hours on the ice tank and at the same time control temperatures thermostatically in the boxes?

V. R. H. Greene.—No.

No. 42.

EXPERIENCES IN THE MANUFACTURE OF PLATE ICE.

By Irving Warner, Wilmington, Del.

(Junior Member of the Society.)

The delicacy of balance in plate ice plants is well known among refrigerating engineers, particularly where the ammonia is fed direct to the freezing coils, thereby necessitating a multiplicity of expansion valves. With a capable plant engineer we have little trouble in this line, but we do know that there are many small points in the management of plate ice plants which necessitate careful watching or the plant will suffer severely in capacity and economy. To overcome these troubles successfully there must first be taken daily measurements of the ice, so that it may be known that the plant is keeping up to its normal capacity and economy of operation before it is possible to know the existence of any trouble.

Power plant economies, such as the weighing of the coal and the metering of the boiler feed, are well known, so they will not be considered here, but in the freezing room it is imperative that the amount of ice the plant manufactures every day be known. It is not sufficiently accurate to take the amount of ice harvested per day, inasmuch as this varies considerably and the trouble might go on for as long a period as a week before being detected. We have, therefore, adopted a system of taking daily measurements of the thickness of ice on every plate in our plant. This is done by having slots cut in the lids of the tanks properly placed over the cakes to be measured, one end of the slots being vertically over the face of the plates. An iron-shod stick is put down through a slot and the end held against the surface of the ice. The stick is brought vertical by means of a level and the distance from the end of the slot over the plate is noted. It is only necessary to measure the cake on one side of the freezing plate. Table I shows the method of entering up and computing the record of the ice that is manufactured daily as shown by these measurements. I give the record for two successive days, so that there may be noted a typical daily increase. We, of course, keep full records of all important pressures and temperatures, but since this is ordinary practice we will not pursue it further here.

TABLE I.

DAILY ICE REPORT OF DIAMOND ICE COMPANY.

OCTOBER 1, 1907.

SECTION A.

Plate No.	Thickness of Ice in Inches.	
1	11	
3	11	
5	11	
2		11
4		11.5
6		11.5
	33	34
Tons ice on plates	16.5	17
Tons ice on plates at previous measurement	14	15.5
Increase, tons	2.5	1.5

SECTION B.

Plate No.	Thickness of Ice in Inches.	
7	11	
9	11	
11	11.5	
8		12
10		12
12		12
	33.5	36
Tons ice on plates	16.5	18
Tons ice on plates at previous measurement	14.5	16
Increase, tons	2	2

SECTION C.

Plate No.	Thickness of Ice in Inches.	
13	4	
15	4	
17	4	
14		4
16		4
18		4
	12	12
Tons ice on plates	6	6
Tons ice on plates at previous measurement	..	..
Increase, tons	6	6

OCTOBER 2, 1907.

SECTION A.

Plate No.	Thickness of Ice in Inches.	
1	12	
3	12.5	
5	12.5	
2		12.5
4		12.5
6		13
	37	38
Tons ice on plates	18.5	19
Tons ice on plates at previous measurement	16.5	17
Increase, tons	2	2

SECTION B.*

Plate No.	
7	Out 34.5 tons of ice.
9	
11	
8	
10	
12	

SECTION C.

Plate No.	Thickness of Ice in Inches.	
13	6.5	
15	6.5	
17	6.5	
14		6
16		6
18		6
	19.5	18
Tons ice on plates	9.5	9
Tons ice on plates at previous measurement	6	6
Increase, tons	3.5	3

TABLE I—*Continued.*

OCTOBER 1, 1907—*Continued.*

SECTION D.

Plate No.	Thickness of Ice in Inches.	
19	11	
21	10.5	
23	10.5	
20		12
22		11
24		11
	32	34
Tons ice on plates	16	17
Tons ice on plates at previous measurement	14	15.5
Increase, tons	2	1.5

SECTION E.

Plate No.	Thickness of Ice in Inches.	
25	3.5	
27	3.5	
29	3.5	
31	3.5	
26		3
28		3.5
30		3.5
32		4
	14	14
Tons ice on plates	7	7
Tons ice on plates at previous measurement	..	..
Increase, tons	7	7

SECTION F.

Plate No.	Thickness of Ice in Inches.	
33	3	
35	3	
37	3	
39	3	
34		3
36		3
38		3
40		4
	12	13
Tons ice on plates	6	6.5
Tons ice on plates at previous measurement	..	..
Increase, tons	6	6.5

OCTOBER 2, 1907—*Continued.*

SECTION D.

Plate No.	Thickness of Ice in Inches.	
19	12	
21	12	
23	12	
20		13
22		12.5
24		12
	36	37.5
Tons ice on plates	18	18.5
Tons ice on plates at previous measurement	16	17
Increase, tons	2	1.5

SECTION E.

Plate No.	Thickness of Ice in Inches.	
25	6	
27	6	
29	6	
31	6	
26		6
28		6
30		6
32		6
	24	24
Tons ice on plates	12	12
Tons ice on plates at previous measurement	7	7
Increase, tons	5	5

SECTION F.

Plate No.	Thickness of Ice in Inches.	
33	6	
35	6	
37	6	
39	5.5	
34		6
36		6
38		6.5
40		6.5
	23.5	25
Tons ice on plates	11.5	12.5
Tons ice on plates at previous measurement	6	6.5
Increase, tons	5.5	6

TABLE I—*Continued.*

OCTOBER 1, 1907—*Continued.*

SECTION G.*

Plate No.	
41	Out 46.5 tons of ice.
43	
45	
47	
42	
44	
46	
48	

SECTION H.

Plate No.	Thickness of Ice in Inches.	
49	12	
51	12	
53	11.5	
55	11.5	
50		13
52		13
54		12.5
56		12.5
	47	51
Tons ice on plates	23.5	25.5
Tons ice on plates at previous measurement	21	24
Increase, tons	2.5	1.5

SECTION I.*

Plate No.	
57	Out 47.5 tons of ice.
59	
61	
63	
58	
60	
62	
64	

OCTOBER 2, 1907—*Continued.*

SECTION G.

Plate No.	Thickness of Ice in Inches.	
41	4	
43	4	
45	4	
47	4	
42		4
44		4
46		4
48		4
	16	16
Tons ice on plates	8	8
Tons ice on plates at previous measurement	..	..
Increase, tons	8	8

SECTION H.*

Plate No.	
49	Out 49 tons of ice.
51	
53	
55	
50	
52	
54	
56	

SECTION I.

Plate No.	Thickness of Ice in Inches.	
57	3.5	
59	3.5	
61	3.5	
63	3.5	
58		4
60		4
62		4
64		4
	14	16
Tons ice on plates	7	8
Tons ice on plates at previous measurement	..	..
Increase, tons	7	8

TABLE I—*Continued.*

OCTOBER 1, 1907—Continued.

SECTION J.

Plate No.	Thickness of Ice in Inches.	
65	11.5	
67	11.5	
69	11.5	
71	11	
66		13
68		12.5
70		12
72		11.5
	45.5	49
Tons ice on plates	22.5	24.5
Tons ice on plates at previous measurement	20	22
Increase, tons	2.5	2.5

SECTION K.

Plate No.	Thickness of Ice in Inches.	
73	10	
75	10	
77	9	
79	9	
74		11
76		10.5
78		10
80		10
	38	41.5
Tons ice on plates	19	20.5
Tons ice on plates at previous measurement	15.5	17.5
Increase, tons	3.5	3

SECTION L.

Plate No.	Thickness of Ice in Inches.	
81	9	
83	9	
85	9	
87	9	
82		9.5
84		9
86		9
88		8.5
	36	36
Tons ice on plates	18	18
Tons ice on plates at previous measurement	15	14.5
Increase, tons	3	3.5

OCTOBER 2, 1907—Continued.

SECTION J.

Plate No.	Thickness of Ice in Inches.	
65	12.5	
67	12	
69	12.5	
71	12	
66		14
68		13.5
70		13
72		12.5
	49	53
Tons ice on plates	24.5	26.5
Tons ice on plates at previous measurement	22.5	24.5
Increase, tons	2	2

SECTION K.

Plate No.	Thickness of Ice in Inches.	
73	11	
75	11	
77	10.5	
79	10.5	
74		11.5
76		11.5
78		11.5
80		10.5
	43	45
Tons ice on plates	21.5	22.5
Tons ice on plates at previous measurement	19	20.5
Increase, tons	2.5	2

SECTION L.

Plate No.	Thickness of Ice in Inches.	
81	10	
83	10	
85	10.5	
87	10.5	
82		11
84		10.5
86		10.5
88		10.5
	41	42.5
Tons ice on plates	20.5	21
Tons ice on plates at previous measurement	18	18
Increase, tons	2.5	3

TABLE I—*Continued.*

OCTOBER 1, 1907—*Continued.*

SECTION M.

Plate No.	Thickness of Ice in Inches.	
89	10	
91	10	
93	9	
90		9.5
92		10
94		9
	29	28.5
Tons ice on plates	14.5	14
Tons ice on plates at previous measurement	11.5	11.5
Increase, tons	3	2.5

SECTION N.

Plate No.	Thickness of Ice in Inches.	
95	7.5	
97	7.5	
99	7.5	
101	7	
103	6.5	
96		8
98		8
100		7
102		7
104		6.5
	36	36.5
Tons ice on plates	18	18
Tons ice on plates at previous measurement	13	13.5
Increase, tons	5	4.5

SECTION O.

Plate No.	Thickness of Ice in Inches.	
105	8	
107	8	
109	7.5	
111	6.5	
106		8
108		7.5
110		7.5
112		7
	30	30
Tons ice on plates	15	15
Tons ice on plates at previous measurement	11	11
Increase, tons	4	4

OCTOBER 2, 1907—*Continued.*

SECTION M.

Plate No.	Thickness of Ice in Inches.	
89	11	
91	11	
93	10.5	
90		11
92		11.5
94		10.5
	32.5	33
Tons ice on plates	16	16.5
Tons ice on plates at previous measurement	14.5	14
Increase, tons	1.5	2.5

SECTION N.

Plate No.	Thickness of Ice in Inches.	
95	9	
97	9	
99	9	
101	8	
103	8	
96		9
98		9
100		8.5
102		8.5
104		8
	43	43
Tons ice on plates	21.5	21.5
Tons ice on plates at previous measurement	18	18
Increase, tons	3.5	3.5

SECTION O.

Plate No.	Thickness of Ice in Inches.	
105	9	
107	9	
109	9	
111	8	
106		9.5
108		9.5
110		9.5
112		8.5
	35	37
Tons ice on plates	17.5	18.5
Tons ice on plates at previous measurement	15	15
Increase, tons	2.5	3.5

TABLE I—*Continued.*

OCTOBER 1, 1907—*Continued.*

SECTION P.

Plate No.	Thickness of Ice in Inches.	
113	7	
115	7	
117	7	
119	6.5	
114		8
116		8
118		8
120		7
	27.5	31
Tons ice on plates	13.5	15.5
Tons ice on plates at previous measurement	10	12
Increase, tons	3.5	3.5

OCTOBER 2, 1907—*Continued.*

SECTION P.

Plate No.	Thickness of Ice in Inches.	
113	9	
115	8.5	
117	8.5	
119	8.5	
114		9.5
116		9.5
118		9.5
120		9.5
	34.5	38
Tons ice on plates	17	19
Tons ice on plates at previous measurement	13.5	15.5
Increase, tons	3.5	3.5

	October 1.	October 2.
Ice in tanks at last measurement	426.0	434.5
Day's increase	102.5	105.0
Total ice in tanks	528.5	539.5
Ice out today	94.0	83.5
Ice in tanks at end of day	434.5	456.0

		October 1.	October 2.
Coal consumed, tons.	Bituminous	4.80	4.75
	Screenings	10.05	9.40
Total		14.85	14.15

		October 1.	October 2.
Ice manufactured, tons.	Compressors 5 and 6	52.5	52.0
	Compressors 7 and 8	50.0	53.0
Total		102.5	105.0
Tons of ice per ton of coal		6.9	7.4

* Liquid feeds are cut off shortly after previous day's measurements are taken, and no credit is given to compressors for this (the last) twenty-four hours. The amount of ice taken from this section is the same as shown in report for previous day.

One of the great essentials in making a plate ice plant maintain its capacity is the continuous operation of the engines at full rated speed. Where the man in charge of the engine room is separated from the man operating the freezing end of the plant the former is likely to ease up his engines for his own benefit and that of his fireman. A revolution counter that is read faithfully every day at the same time puts a check on this. It also assists in placing the responsibility when the men in the freezing room blame the engine men for a decrease in capacity. The latter, if they have done their duty faithfully, are exonerated.

There are probably no compressors that have a larger array of valves to be taken care of than those that come under my observation. The low pressure cylinder has seven suction and three discharge valves in each head. The high pressure cylinder has two of each, making a total of twenty-eight valves in one machine, and there are two machines. It is rare that I have been able to detect experimentally a defect that our engineers were not already aware of practically. Any defect in the high pressure cylinder results only in loss of economy if clearance is zero. This loss is manifested by a rise of the intermediate pressure. Careful listening to the exhaust in the oil trap places the responsibility in one end, and then it is a matter of one of four valves.

A defect in the low pressure cylinder results in both loss in economy and decreased capacity. It is usually first detected when the engineer finds that he cannot keep the back pressure down and the intermediate pressure drops a little. If a suction valve is at fault it can often be detected by the fact that it runs warmer than usual; but this is rather difficult when the valve adjoins a discharge valve, and is consequently warmed by it.

The above are the "rule of thumb" methods of the plant engineer, and with a good, careful man are fairly satisfactory. However, it is well to be able to place troubles more accurately than this, in order to save the time of shutting down to look over valves that are in good condition, and I have, therefore, hit upon a combination of tests which makes it quite easy to centre the responsibility with a fair degree of accuracy.

You heard last year a discussion on the value of thermometers for testing compressors. I believe in this practice thoroughly, and have had thermometer cups inserted in the common suction and the individual discharge lines of each cylinder. The mere fact that one discharge pipe is warmer than the other is sufficient evidence that the valve is at fault. In general, however, the crank end runs warmer

than the head end, and this must be determined experimentally when it is known that the compressors are in good condition. With us this difference is about 6° Fahr. We can assume with reasonable accuracy that the rise in temperature over the normal rise is an index of the loss. For instance, if the gas entered at 50° and is discharged at 200° at one end and 215° at the other end, assuming that when the compressor was operating perfectly the two discharges were equal, the loss in one end is the ratio of 15 to 150, or 10 per cent. Since this occurs in only one end of the engine, the total loss is but half, or 5 per cent. Thus it is seen that a comparatively small loss can very quickly be detected in this way. Having located the cylinder end which is at fault, it is then to be determined whether the trouble lies with a suction or discharge valve. This may be done by taking a double indicator diagram of the two ends of the cylinder on the same card. These diagrams should properly have their compression lines intersect at the centre of the card. If the thermometer has shown a serious error, one of these compression lines will lie above the other at the centre. If the compression line of the offending end is above that of the other end, it proves that its discharge valves are leaking back, and if the line is below, the fault is with the suction valves.

In plotting adiabatic curves on diagrams, Mr. Voorhees, in his useful little book, "Indicating the Refrigerating Machine," has given us a set of constants for various back pressures. I make the following suggestion, which I believe to be an improvement in practical accuracy and ease of working—its theoretical accuracy I cannot vouch for. An examination of Mr. Voorhees's tables reveals to you that all of his numbers in any one column bear the same ratio to the first as any other corresponding number does to the first of its column. I give a list of these ratios in Table II. They are the same as Mr.

TABLE II.

ADIABATIC RATIOS.*

P =	1.000
P9 =	1.147
P8 =	1.336
P7 =	1.590
P6 =	1.944
P5 =	2.465
P4 =	3.285
P3 =	4.780
P2 =	8.133
P1 =	20.000

* Calculated from "Indicating the Refrigerating Machine," by Gardner T. Voorhees.

Voorhees would have put in his book if he had calculated for one pound back pressure. On the diagram, Fig. 1, I lay off the absolute zero line below the atmospheric line, according to the scale of the spring used. Then with the 100th scale I measure the vertical distance from this line to the beginning of the compression line. This, in hundredths of an inch, is my base figure. The diagram is divided

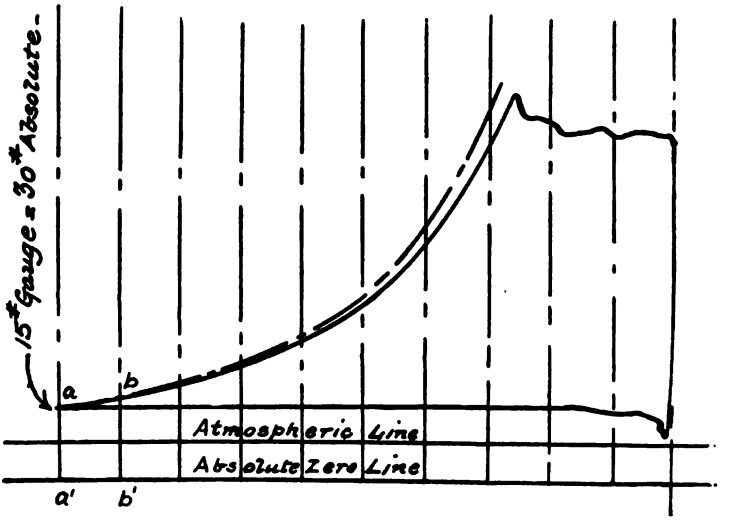

FIGURE 1.

into ten parts by vertical lines, according to Mr. Voorhees's instructions. I now multiply my base figure by the second ratio and lay off the amount on the second ordinate above the zero line, etc. The adiabatic is thus developed.

While the combination thermometer and indicator test, without any computations or past data, is sufficient for double-acting compressors, it will be found necessary in single-acting compressors to always plot the adiabatic line and keep a line of data on the normal rise in temperature for various back and condensing pressures.

Last year I put myself on record as being in favor of concrete tanks. I now retract that and declare once more in favor of wood construction. I have had no experience with steel tanks. An examination of wood tanks that have been in service seventeen years shows them to be in perfect condition. I believe that cold water acts as a preservative, and that the wood will last indefinitely, so long as the tank is in service. Careful and liberal design is all-important, and all

joints of planking should be exposed for calking from the inside of the tank. If only one large tank with bulkheads is installed these bulkheads should be well provided with rods. The alternating pressure due to water being taken out of one side or the other for any reason is very hard on them.

Few plant engineers realize the loss occasioned by leaking tanks, as the water must be replaced by warmer water, with consequent loss. The gradual reduction in our capacity of about 20 per cent. was found due to the cause that the engineer was replacing the heavy leakage with water from the fore-cooling tank and continuing serenely with his affairs. Since we learned this lesson we put a meter on the water main to the fore-cooling tank. This then shows the total water going to the tanks and by differences gives the loss by leakage, wastage or harvesting.

In designing freezing plates for plate ice plants, the choice of two evils is offered to the engineer—either have the two ends and the bottom of the plate of ice rounded off in freezing, or install end and bottom melting-off pipes. If the former method is adopted it is done by merely making the coils sufficiently smaller than the plate, so that the freezing does not take place beyond the limits of the plate; then in melting off with warm gas or other means the ice has to free itself from nothing but the plate. The result, though satisfactory from a manufacturing standpoint, is bad commercially, inasmuch as when the plate is cut up into cakes about 50 per cent. of these have the rounded edges, making a larger loss in disposing of the ice. We have adopted the other plan, and at present effect our melting off the edge by having steam pipes down the inside edge of the plate, continuing across the bottom and out through the wall of the tank. In the space of 12 inches—the thickness of the ice—there are three of these pipes, and they are connected at the inner top end by a header, which has a connection for a flexible steam pipe. The pipes across the bottom are placed at a slight grade, so that the condensation from the steam in melting off automatically drains itself. This is absolutely necessary, as the pipes would otherwise be frozen and burst in the next freezing period. The outer edge of the plate of ice is taken care of by having a sheet of galvanized steel set out from the wall of the tank a distance of 1½ inches. This space, of course, freezes with the rest. It is melted out by running a live steam pipe with a T-end down through it. This operation releases the plate of ice. Melting off the main plates is effected by turning in ammonia gas from the condensers to the freezing coils.

I am frank to say that our method of melting off the ends and

bottom is not at all satisfactory. Pipes fail to drain, and melting down the outside ends must be done with water in the tanks on account of the water that would otherwise be blown out. This, of course, warms the water and melts the ice. We have fitted up one section of our freezing room with brine coils for this service. The brine is warmed by the exhaust steam from the pump which drives the brine through the coils. The brine passes down the pipe at the outside and across the bottom up the other end, and then returns the same way, making the round trip three times. It then returns to be rewarmed. Each plate has its own coil connected to the pressure and return brine headers. These coils are faced with galvanized steel plates and grouted into a solid mass with cement and sand. In installing care must be taken to give sufficient draft so that the ice when melted off will come out easily. A total of 1½ inches horizontally and the same vertically is sufficient. This method has so far proved very satisfactory, and we are waiting to see whether it will stand up well without excessive repairs. Unfortunately, it is very expensive to install, the cost being in the neighborhood of $30 per ton of daily capacity.

I can give you perhaps some very interesting information on back pressure. As I have stated before, we have two compressors which are exact duplicates. During most of the year we run both of these machines, each one acting entirely independently and doing its share of the freezing. The piping is so arranged that we can throw either machine on a part of the freezing room or one machine to all. Unfortunately, our freezing room is not sufficiently large for our power plant, with the result that when we have only one engine running it is possible to make that engine carry three-fourths of the entire freezing room. This automatically results in a continuous higher back pressure, and figures given in Table III show results of such a test. I will say further that the daily ice manufactured—108 tons for two engines—is an exceptionally high record and only rarely reached, but 100 tons is a better average. You will note that the condensing water and the temperature of liquid ammonia were somewhat in favor of the period when both engines were running. The important point is that one engine when handling nine sections was doing 32 to 40 per cent. more than when the two were handling twelve sections. The rise in back pressure to 17 pounds is about what would be expected. You can see the result for yourselves, as the ice manufactured is roughly proportional to the back pressure. I would remind you, however, that this can only be done in periods of cool weather, since when the summer weather comes on the back

pressure, with both engines working, rises of itself. Taking our plant, for example, I would expect, therefore, that a 50 per cent. increase in the freezing room would result in about a 40 per cent. increase of capacity for perhaps half the year. Our capacity drops off comparatively little in the very warm weather of summer, less than 10 per cent., and I attribute it to the reason that the freezing room is sufficient for the compressor equipment in hot weather, but is not sufficient in cool weather.

We have also carried on tests with an idea of obtaining the results from running with a very low back pressure. The figures in the last three columns of Table III show the results obtained from

TABLE III.

	Two Engines. Week Ending December 10, 1905.	One Engine. Week Ending November 24, 1905.	Two Engines, October 12-25, 1903.	Two Engines.	One Engine.
Back pressure, pounds gauge....	12	17	15	4.8	4
Tons ice manufactured.....	108	71	99	77	44
Condensing water temp., degrees Fahrenheit	38°	44°	55°	37°	36°
Liquid ammonia, degrees Fahrenheit	58°	62°	75°	53°	54°
Return gas, degrees Fahrenheit..	39°	39°	—	—	—
Sections working.....	12	9	13	8	4

operation in this way. You will note that fewer sections can be operated and the rate of freezing per section is much higher, but the total ice manufactured is considerably lower. In my opinion this test, combined with the previously noted test of higher back pressures, proves conclusively the advantage of operating under the higher back pressure, provided the plant is so designed. This practical work merely bears out the theory on this point.

In conclusion, it may be of interest to you to know the division

TABLE IV.

STEAM CONSUMPTION IN POUNDS PER TWENTY-FOUR HOURS.

	Total.	Per Cent.
Two compressor engines.....	125,703	69.60
Auxiliary engine and pumps.....	45,347	25.10
Dynamo engine, 12½ hours.....	5,152	2.86
Harvesting, 26 cakes.....	3,088	1.71
Melting off, 26 cakes.....	1,290	.73
Total	180,590	100.00

of steam consumption as we determined it from a test made in the spring of 1903. There have been no important changes since then, so this test, Table IV, should still be an index of the operation of the plant, with a probable exception that our steam melting-off pipes are now in such bad condition that the amount required for harvesting is considerably in excess of what is given here. I would be very glad to have any comments upon this.

The amount of steam required for our auxiliary work is high, because we have an enormous amount of pumping to do to get our condensing water. The figures for melting off in harvesting are probably at present two or three times greater than when this test was made. In any event, it is a comparatively small percentage of the total.

DISCUSSION.

Thomas Shipley.—Will Mr. Warner explain how his freezing coils are connected up? I would like to know where the evaporating pressure was taken, whether it was at the end or at the beginning of the system? What was the size of the compressors and the size of the plates?

Irving Warner.—The compressors are duplicates, two of them. The low-pressure ammonia cylinders are connected with the low-pressure steam, and the high-pressure ammonia cylinders are connected with the high-pressure steam. The strokes in both cases are 36 inches. The diameter of the low-pressure ammonia cylinder is 17 inches and that of the high pressure 11½, and the compressors hold up pretty well to 50 tons apiece. Some sections have three plates, some have four, and one has five. We notice no difference between the three- and five-coil sections, the plates being connected in series. Our freezing coils are made of 1½-inch pipe, return bends being on 7-inch centres. The liquid ammonia goes down the vertical pipe and enters the bottom horizontal pipe. The ammonia then comes out of the top of this coil and enters the bottom of the next coil in series, and so on throughout the section. As I have said, we have sections comprising three, four and five coils. On one or two occasions I have been asked what was the drop in pressure from the expansion valve to the end of the last coil. I myself have never carried on any test, because it means stopping the plant and pumping it all out and putting on a gauge. That costs money. I believe that in tests that have been carried on before me the drop in pressure has been 2 or 3 pounds in ordinary working. To a great extent that can be made anything you want. If we find that the first coil is freezing too rapidly and the last coil is not freezing rapidly

enough, that would indicate that the expansion valve is not open enough—that is, if the opening of the expansion valve is very small, the first coils rob the succeeding ones. However, if the valve is opened a little more all the coils do their work properly. If it is open too much, the last coils of the series freeze rapidly and the first ones do not. This is due to the fact that the ammonia is admitted so rapidly that the first coils operate under a higher back pressure due to the resistance of all this pipe in series. That is a point of practical application which our engineer in charge seems to have mastered very successfully. There are sixteen sections in our plant; that means thirty-two expansion valves. There does not seem to be any particular trouble with them.

Thomas Shipley.—Tell us where what you call your indirect feed tanks are, and where you let the liquid ammonia trap out of your main suction.

Irving Warner.—Our compressors are, unfortunately, of a design which precludes them from taking the return ammonia gas at a low temperature. The suction and discharge valves are located in the same heads, the compressors being double acting, with the result that if the temperature of the gas is less than about 50° Fahr. the difference in temperature between the gas in the suction and that in the discharge is so great that the heads expand unequally, with a loss of ammonia through the packed joints between the heads and the cylinder. We overcame this to some extent by passing all our return gas through our water storage tanks, called fore-cooling tanks, with the idea of superheating the gas to the desired temperature. This was only partially successful, so about three years ago we introduced a Cochrane separator into each suction line before it entered the fore-cooling tank. The liquid thus separated out was used to feed three small sections of three plates each. In place of the ordinary method of connecting these plates up in series, we had a header from which each plate received its own liquid ammonia discharge into a return header, which was in turn connected back into the suction pipe. Between the separator, where we took off the liquid, and the return pipe back into the suction, we placed a valve which we throttled somewhat so that the difference in pressure is one pound or less. In case we cannot get enough liquid in this way we have, in addition, a direct liquid feed from the liquid main. These indirect feed sections do not always work regularly, the ice freezing thicker on the bottom and thinner at the top. Also, the plates froze with different rapidity, so that in practical working we are obliged to give them individual throttling. Both of these diffi-

culties are overcome to a great extent by careful watching. The piping as now arranged has in it, owing to structural difficulties, a goose neck, which undoubtedly fills with ammonia gas, preventing the proper flow of the liquid ammonia from the separator. The proper installation of this piping should be such that there should be a continuous downward course of the pipe from where it leaves the separator until it gets to the bottom freezing coils, so that any small amount of vaporized ammonia could bubble up freely through the liquid and free itself through the separator, thus having no gas trap in the circuit. We would then have an almost solid liquid head from the separator down to the bottom of the coil; whereas the return through the coil and the pipe connecting the return to the suction again would be a combination of liquid and gas. This latter being much lighter, there would be a natural flow of the liquid ammonia down from the trap through the coils, and a return of the gas to the suction pipe.

Thomas Shipley.—From what side of the throttle valve do you take your back pressure records?

Irving Warner.—We have at that point a gauge with double connections and valves for taking pressure on either side of the throttle valve.

Thomas Shipley.—The back pressure would be about 2 pounds higher.

Irving Warner.—No; we vary that. You can scarcely notice the difference on the gauge. We never get over a pound, and we prefer to have about half a pound.

Thomas Shipley.—The reason I called attention to this, Mr. President, is because it was from the plant that Mr. Warner has described that I got the information which led me to make the experiments which brought out the flooded system for evaporating ammonia, and I found that the method used on the Warner plant was not as effective as the use of a trap which would separate the liquid from the gas passing through the suction pipe, allowing the gas to go on to the machine while the liquid went back to the evaporating coils to do useful work. Our company has built quite a number of plants using the flooded system, and we have had remarkable success with them.

Irving Warner.—We have not gone as far with this as we would have liked. In arranging these sections for indirect feed we have taken them from the direct expansion, and we are already deficient in freezing room, so that the advantage is not perhaps as much as it should be. What is your opinion, Mr. Shipley, of tapping a pipe

into the top of the goose neck, which now traps full of gas, and connecting that pipe to the suction, so as to relieve this gas trap and thus get a full liquid head on the coils?

Thomas Shipley.—If I were going to revamp that plant I would do away with the choke valve and run the suction into a trap, so that the liquid would drop down to the bottom pipes in the coils of the section you use to dry the gas, then there would be no trouble; all the gas going to the machine would be dry. If you wanted to superheat it you could run it through your water storage tank.

Irving Warner.—The connection from the separator to the headers is quite a large pipe, much larger than necessary if we had a true liquid feed. If we could only trap away the gas from the goose neck, I am sure we would have ample capacity. I think the gas interferes with the operation.

Louis Block.—Why do you not try trapping it away?

Irving Warner.—It did not occur to us until after last year's repairs, and, of course, it is better to keep the machinery going.

Louis Block.—Is Dr. Krebs alive?

Irving Warner.—Yes, but he is not in the ice business nor ammonia business now.

Louis Block.—He lives in Wilmington?

Irving Warner.—I believe he does, but his business is in Newport, Delaware.

Louis Block.—What made you change your mind about wood and concrete?

Irving Warner.—The concrete tank is not sure enough. You may have an excellent job which may not cost you a cent in repairs, but if the concrete did develop a crack I do not know how it could be repaired. A careful examination of our tanks, subsequent to last year's meeting of the Society, showed that the wood was in excellent condition on a tank seventeen years old.

Louis Block.—Then you have had no experience with concrete tanks, but with wood tanks your experience has been very satisfactory?

Irving Warner.—So satisfactory that we do not see any reason for changing them.

Louis Block.—I want to ask another question. You stated that the increase of discharge temperature did indicate loss; that certainly could only take place if a suction valve is at fault, not with the discharge valve?

Irving Warner.—Yes; you are mistaken about that, because if the discharge valve is at fault, gas, which is already hot, having been

compressed, goes back into the compressor and is again compressed, with further rise in temperature.

Louis Block.—Did you take the temperature; you may have 100° above your normal discharge?

Irving Warner.—I said that the end of the cylinder which runs warmest is at fault.

Louis Block.—Exactly; and then you said that the loss was in direct proportion to the temperature?

Irving Warner.—I said that, roughly, the loss is in direct proportion to the rise of the temperature.

Louis Block.—That cannot be the case, because the temperature has no relation to what the loss would be.

Irving Warner.—I said, roughly, because I did not go into any calculation or assumption.

Louis Block.—You stated also that the discharged temperature at the crank end was always in your case 6° higher?

Irving Warner.—Yes.

Louis Block.—To what do you attribute that?

Irving Warner.—I have thought over that a good bit. Six degrees rise on our engine represents a very small per cent. The piston rod is there, it is true, but on the other hand the piston rod is so infinitely small, compared with the area of the cylinder wall, that it comes to comparatively nothing. Compare the difference between a 2½-inch rod with a 17-inch cylinder. I think that the stuffing box being at the end keeps the whole head a little warmer, and the gas in entering through the valves is preheated.

Louis Block.—That heat would be communicated to the rod and from the rod to the gas?

Irving Warner.—Yes, but the gas enters through the valves, which have an effective opening of about 1¾ inches in diameter. The gas also has a very circuitous route through the head, and comes into intimate contact with the various parts of the head casting. The stuffing box runs hot, and we have to run a stream of oil on it all the time. I am of the opinion, therefore, that the stuffing box warms the whole head and that this in turn heats the gas.

Karl Wegemann.—What is the size of the plate?

Irving Warner.—The plate of ice as frozen is a little less than 14 feet long; about 13 feet 6 or 9 inches.

Karl Wegemann.—About 10 feet deep?

Irving Warner.—Yes; about 10 feet deep, 9 feet 8 inches or something like that.

Karl Wegemann.—The thawing-off system is also used at the bottom of the tank?

Irving Warner.—Yes, the same coil melts off both ends and bottom. The pipe is embedded in cement and faced with galvanized iron. This facing at the ends is given a three-quarter inch draft, both with respect to the perpendicular of the plate and to a horizontal line, so that the plate of ice in melting off can free itself in moving away from the freezing coils and in moving upwards. We have this three-quarter inch draft on each end, so that the total draft on the length of the plate is 1½ inches. It should be at least this, because the grouting behind the plates is very hard, and since it is almost impossible to get the plates perfectly smooth there would be great resistance to the removal of the ice were the draft less.

A. A. Cary.—In making up the plans showing the disposition of steam I would like to ask Mr. Warner how he found the amount of steam used for melting off and in small pumps; those are rather difficult determinations to make.

Irving Warner.—That was a rather difficult test to make, and so we had probably to do a little more in the way of differences of known amounts than a very accurate test would allow. We knew the amount that the main compressor engines were taking at all times by weighing their water of condensation. The steam used by the dynamo engine was estimated by its kilowatt output and the steam consumption per kilowatt hour for a machine of this small size. We metered the entire supply of water to the boilers, so that there was a considerable period in twenty-four hours during which the auxiliary engine and pumps received the difference between the total feed and the water of condensation from the main engines. We have steam ice cutters made of copper tubes, through which live steam flows, which cut off five cakes at a time in cutting up the plates. By immersing these in a shallow tank of water we determined how much steam per minute these cutters consumed, and by noting the number of minutes run in the twenty-four-hour test, we determined the amount of steam used in cutting up. The final factor to be determined is that of melting off. Since all this occurs in a comparatively short period of the twenty-four hours, it was approximately determined by the increase of steam consumption over what it should naturally have been during this period. Such factors as blowing off the boilers, difference of level in the boilers, etc., were considered in our calculations. While the results are probably far from accurate, we have an approximate idea of where the steam is being used. You will note that the sum total of harvesting and melt-

ing off is only about 2½ per cent., so that if we made a mistake in these items of even so much as 100 per cent., it would still be but a small factor of the total.

John E. Starr.—I do not like to leave this subject of concrete tanks without further discussion. There may be other members who have had experience with concrete tanks besides the Chairman. Perhaps Mr. Abram Day could tell us something on that subject?

Chairman Wills.—I was thinking the same way. I thought that we should not let the concrete tank be dynamited, but give it a show for its life, as that is the only way to treat a concrete tank. I think Mr. Day has told me—I do not think I am giving away any secret—that he has put up a great many concrete tanks, in fact has never had a failure. I think Mr. Day can enlighten us on that subject.

Abram Day.—I came here to listen and learn. I did not expect to be called upon to speak, but as to concrete tanks I may say that I first experimented with them about six years ago. I had a small refrigerating plant for freezing ice cream, and I built a well of 2 by 3 feet and 3 feet deep; in fact, I built five. The fourth was pretty nearly successful, the fifth was successful. I cast the fifth in the ground, and about three months afterward I tested it with water by placing small coils in it and freezing the coils perfectly solid, right together. I did that three or four times, and let them thaw out each time, and the concrete to-day is just as good as it was five years ago. I built a set of concrete tanks for Mr. J. Frank Post, Newark, N. J., three years ago, for making plate ice. Six were 20 feet wide, 12 feet 1 inch across, and 12 feet deep; the seventh was of the same dimensions, except on the long way it was 17 feet. We put five coils in each of the six tanks, and in the larger one we put seven. We made the tanks 112 feet over all. Those tanks would hold water just like a glass bottle.

Mr. Post had built a spruce tank and when the tank had run three years it began to leak. It could not be calked from the outside, so we calked it from the inside, and this was done yearly for three years after that. If you have to calk a tank such as Mr. Warner has described, with all the thawing coils at the side, it will cost about half as much as the tank is really worth. That is one of the troubles we do not experience in a concrete tank. The concrete tank is of reinforced concrete. There is nothing but the concrete that holds the water; there is not another thing on it to make it hold water. In the summer of 1907 I built an ice plant at Kearny, N. J., which contained a tank like Mr. Post's, with the exception that the blocks of ice are 19 feet long. Therefore the tank is about 18 inches deeper. I have seen cases

where the ice freezes up to the wood tanks and rots the wood very quickly. These concrete tanks all hold water perfectly. They were built outside and were not finished up to the first of this year. I had to keep fires in them and keep them covered. After the concrete sets for about forty-eight hours and is made of a good rich mixture and warmed a little, the frost does not seem to have any effect upon it. I had occasion to go into the fore-cooler of the tank I built for Mr. Post, and I found some of the concrete chipped off a little. In my experimenting with concrete, when I started on the concrete tanks, I made the concrete mass thin, and after it was dry I froze it and then thawed it; froze and thawed it again, and put it down to zero, sometimes a little below, and I found that by freezing and thawing it in the same day it would not stand more than ten or twelve tests, without cracking; so I found that I had to keep the ice away from the concrete. I found the same difficulty when the frost gets to the wood. Frost makes wood porous; it expands it very much, especially a wood like spruce. I built a plant at Roseville, near Newark, N. J., over six years ago, for the Orange Mountain Ice Company. This year it was remodeled and I put in the same system that is used in Mr. Post's plant, because it is more economical, and in that way built five concrete tanks again, one tank with bulkheads. I always put in the bulkheads, so that we can drain off the water. The well water is poor, so city water is used, and the tanks are drained about every other day, because otherwise the ice becomes yellow. The water from the rock is hard and contains lime, and that is the reason we put in bulkheads. I gave the tanks built at Rockaway Beach a little overseeing. They are built out of the ground and insulated. I am told that they hold water to perfection. They are on view and anybody can see them. A concrete tank, I find, can be built at one-third less cost than a wood tank. We built a wooden tank for the Orange Mountain Ice Company, but before we were finished with it it cost $7,000. A concrete tank for the same amount of ice can be put in for half of that amount. These plants can be seen running. The one at Kearny is running right straight along. The buildings of the Orange Mountain plant caught fire, and so we built two buildings for the tanks, but not for the machinery.

H. D. Stratton.—What mixture of concrete do you use?

Abram Day.—I get fine trap rock, known as screenings, and I put enough sand in it to make a mass, one part of sand, four parts of rock and one part of cement. This is the mixture I generally use. In the tank I built in Kearny I had to use one and a half of sand, two and a half of stone, and one of cement.

Edgar Penney.—What is the size of the stone?

Abram Day.—Screenings. The best job I have done is the one at Kearny, because the stone was small; it may be compared with rice coal.

Edgar Penney.—How many to the inch?

Abram Day.—It may have measured about three-eighths of an inch, while the stone we get from the mountains will go over that, maybe three-fourths of an inch; but the other may not be over one-fourth, and it varies down to dust.

Edgar Penney.—What cement do you use? Portland?

Abram Day.—Yes; but I have had the best of success with Vulcanite. I find some that will not stand cold as well as others. I use enough sharp sand to make a mass. I have had a stone that had enough dust with it to use without sand; nothing but screenings and cement. At Kearny we got such a clean stone that it took one and a half of sand, two and a half of stone, and one of cement to make the mass.

A. A. Cary.—Do you use reinforcing bars?

Abram Day.—Yes; I generally use about half-inch round steel, and I weave the rods together just as one would weave a sieve, and at the bottom of the bulkheads I put in some 2½-inch T-irons, about 18-inch centres.

Edgar Penney.—How thick are your tanks?

Abram Day.—I make the bulkhead about 12 inches thick and the side walls about 10 inches thick.

John A. Ruddick.—Do you finish the inside of the tank?

Abram Day.—We work them up in the rough. I generally wash them with cement.

John A. Ruddick.—What is the difference in cost as compared with iron tanks?

Abram Day.—I do not know; I have had no experience with iron tanks. I can assure you I would not want to come into New York to build tanks for the price I mentioned. The set of tanks I built in Kearny cost about $400 more on account of the thawing and the frost and other troubles we had. Those tanks were 112 feet long by 13 deep by 20 wide.

Karl Vesterdahl.—How much did they cost?

Abram Day.—Their cost was $3,400.

H. D. Stratton.—For what size of machine?

Abram Day.—Sixty tons of ice. The plates of ice were 12 feet wide and 19 feet long; 6 tons to the block. There are no T-irons in the corners, the steel rods are all woven one into the other.

Guy B. Smith.—How many tons of coal did you use?

Abram Day.—We conducted a test that ran seven days and eight hours in the month of May. We sold 56 tons of ice a day. That was from rice coal and it would average about 19 or 20 per cent. slate. I had plenty of water at 52°. We fitted an ammonia compressor with a Corliss engine and used it to pump the water from the wells. The plant is a remodeled 50-ton plate plant.

Edgar Penney.—In making up your tank you built a wood form?

Abram Day.—Yes.

Edgar Penney.—Then you put in the concrete?

Abram Day.—Yes.

Edgar Penney.—Did you ram the concrete?

Abram Day.—Very little; if I build 6 feet at a time, I have to be careful to keep the thing running right or I will get combes in the concrete.

Edgar Penney.—Do you build in layers?

Abram Day.—We generally try to build in three or four layers. That is to say, the bottom will be laid and then the forms are put up. When they are up, we run in about 3 feet of the wall, then put in another 3 feet, and afterward put up scaffolding to finish.

Edgar Penney.—All the way around?

Abram Day.—Yes.

Edgar Penney.—In an endless band?

Abram Day.—Yes.

Edgar Penney.—What do you do on the morning after the previous day's work is set; what do you do to make a good bond?

Abram Day.—We generally try to build one tank right up; finish that up to the top, if we can. If we cannot, we break up the top in the morning and pour cement and water in and then start in again.

Edgar Penney.—You sprinkle cement or something to establish new binding surfaces?

Abram Day.—Yes.

Edgar Penney.—As you fill the forms, from what height do you drop the concrete?

Abram Day.—Not over 3 or 4 feet.

Edgar Penney.—Do you ram it then?

Abram Day.—We wash it around; we put the mixture in so soft that it will run without any ramming. I always have a man go around and see that everything is all right.

Edgar Penney.—You do not have to ram it to fill up the holes or voids?

Abram Day.—No.

Edgar Penney.—It is soft?

Abram Day.—Yes.

Edgar Penney.—Then would you not describe your concrete as grout?

Abram Day.—Yes.

Edgar Penney.—So wet that it will run off a shovel?

Abram Day.—If you do not make it very soft the lime and the cement do not get a good chance to work.

Gardner T. Voorhees.—As these remarks of Mr. Day's will be printed, I want him to state how many tons of ice he makes per ton of coal in this climate.

Abram Day.—I took a job to build a plant and guaranteed 10 tons of ice for every ton of coal. The manager said that in one week we used 5 tons of coal, and we made the full quantity of ice, 50 tons.

Gardner T. Voorhees.—Then you would say that you made ten to one?

Abram Day.—Yes. If a customer will give 4 gallons of water per ton, I will give him 10 tons of ice per ton of rice coal, and if he will give me clean coal I will give him 12.

Edgar Penney.—Your mixture seems to be more the character of cement grout?

Abram Day.—Yes.

Edgar Penney.—I did not exactly understand; I was not able to apply the word concrete as distinguishing the mixture that you use. You employ it as grout that can be poured into the forms from a pail?

Abram Day.—If you watch concrete work, at least the reinforced concrete buildings that go up around our place, you will find that the mixture is so soft that it will run to where you want it.

Edgar Penney.—Do you use a quick- or slow-setting cement?

Abram Day.—I could not say much about that. I have used both. Vulcanite is slow and it is the best.

Edgar Penney.—How long would it take before it set?

Abram Day.—That depends upon the weather and the temperature of the mixture.

Edgar Penney.—Take it in the fall, not too warm and not too cool?

Abram Day.—Twenty-four hours after I have poured the stuff in I have taken the forms off.

Edgar Penney.—Ordinarily it would be quite hard in the course of three or four days.

Abram Day.—It takes six or eight hours to make any sort of cement.

Edgar Penney.—That would be very slow.

Abram Day.—If you call it slow, it is slow. I generally leave the forms on this time of year forty-eight hours; in summer time or early fall I would take the forms off in twenty-four hours.

Edgar Penney.—You have tanks in use over seven years?

Abram Day.—I built an experimental tank six to seven years years ago.

Edgar Penney.—Do you notice that the cement is very much harder now than seven years ago?

Abram Day.—No; I did not notice that.

Edgar Penney.—It takes about twelve years for cement to attain its greatest degree of hardness.

Abram Day.—So I understand.

John C. Sparks.—The wetter you have the concrete, the more porous it is?

Abram Day.—That may be the case, but I have never had any leaks.

John C. Sparks.—When you make a concrete tank of that very wet grout, do you not find it is porous?

Abram Day.—No. I never had one of my tanks leak yet.

No. 43.

FIREPROOF COLD STORAGE WAREHOUSE CONSTRUCTION.

By John E. Starr, New York, N. Y.

(Member of the Society.)

The scope of this paper is intended only to include examples of cold storage fireproof construction coming under the personal design and supervision of the writer, it being deemed that a complete résumé of the whole field would take up more time than could be allotted to a paper on this subject.

Three classes of fireproof construction are included.

Class A.—Cold storage buildings erected with outer and inner walls of tile, the outer wall not carrying any weight but its own, and the floors a combination of concrete and tile, weights carried on the inner walls and partitions. Insulation between inside and outside walls a continuous fill.

Class B.—Cold storage warehouse containing an inside building, with reinforced concrete columns and girders, and with floors of either reinforced concrete or combination of reinforced concrete and tile, all weights carried on columns. Outside walls either of brick or tile, or a combination of both. Inside walls of vitrified tile. Insulation between inside and outside walls a continuous fill.

Class C.—Cold storage building with iron framework, with weights carried partially on columns and partially on outside brick walls, all iron work covered with fireproofing. Inside wall of vitrified tile. Insulation between inside and outside walls a continuous fill.

Of the first class mentioned (all tile) one example may be quoted of a three-story house in Washington Court House, Ohio.

This house consisted of an outside wall of two 4-inch hollow vitrified tile, an inside wall of one course of 4-inch vitrified tile standing 8 inches away from the outside wall.

The floors rested on the inside wall and on the partitions, which latter divided the house into three sections.

The floor was carried only to the outer edge of the inside wall and rested on it, hence there was a continuous space 8 inches wide

between the inside and outside wall, and also between the edges of the floor and the outside wall. This space was filled with granulated cork, making an unbroken fill from bottom to the small garret, or a circulating air space between the top floor of the cold rooms and the roof. The top of this filled space was closed with tile which could be easily taken off, so that if any settling occurred it might be observed and filled in.

Experience of four years has shown, however, that little, if any, settling occurs.

Experience in filling an 8-inch space also showed that the cork would not "bridge" and leave voids in the 8-inch space even when filled from a height of 20 or 30 feet.

The inside wall was therefore entirely surrounded by insulation and no heat could pass through it without first passing through the cork, except at the very small areas where the inside and outside walls were tied by extending the partitions through to the outside wall.

The tile was laid up in cement mortar and panels of outside wall surface 25 feet wide and 33 feet high have successfully withstood wind pressure and all outside influence.

In this particular building the floors were of the well-known Johnson type. This consists of a reinforced concrete tension member about an inch thick covering the entire span or "bay." On top of this two courses of 6-inch tile were laid, and finally a finished cement wearing floor.

It will be observed that this method of construction places the tile in compression while the thin concrete, with its strengthening rods and web, is in tension.

Long spans can thus be successfully built to carry far in excess of the maximum cold storage load of 400 pounds per square foot.

Unless the difference in the required temperatures be too great in rooms above and below this floor, the double tile is a sufficient insulation in a going house reasonably full.

Should wide differences of temperature be required in rooms above and below a given floor it can be insulated as hereafter described.

Partitions were made with double 4-inch tile with from 6 to 8 inches of cork-filled space between.

The complete success of this type of insulation encouraged the writer to essay the building of larger warehouses containing from one and a quarter million to one and a half million cubic feet, and of

from seven to nine stories high. These buildings come under Class B.

The architectural problem presented in the high building and differences in cost of material led to somewhat different form of construction, though the main principle was followed of a building complete in itself entirely surrounded by insulating material, such material being protected by a weather wall carrying no weight but its own.

The first building of this type was nine stories high, and was built in St. Paul, Minn. The building proper was entirely carried on columns very much as our present skyscrapers are built, excepting that they were all of reinforced concrete, and the outer skin was not carried on the outside girders as in the case of office buildings. Instead of this the outside wall was entirely independent of the main structure and standing about 8 inches away from it at all points.

The outside wall was only 12 inches thick from bottom to top, but was reinforced by an imbedded I-beam framework in which the columns and cross beams ran parallel to the columns and outside girders of the main structure.

It was tied to the main structure at the heads of columns by an iron rod embedded in the concrete floor near the head of the column and attached to the paneled iron framework of the outside wall.

There was thus only about a square inch of conducting material between the outside wall and the inside structure at the head of each column, or rather, say, at the corners of a panel about 11 feet by 15 feet. This conducting area therefore was only a very small fraction of 1 per cent. of the total area, and its conducting effect practically nil as compared with the total.

To provide for the inevitable shrinkage of the inside structure when the refrigeration was turned on, and a corresponding expansion of the outside wall from the sun heat, these ties were arranged to slide so that, no matter how contrary might be the movement of the inside structure and the outer wall, they would still hold the outer wall in place against wind thrust from the outside or the thrust of the insulation from the inside, or ordinary settlement.

As the floors and outside columns and girders were thus about 8 inches from the outside wall it was only necessary to build from floor to ceiling a 4-inch vitrified tile wall and fill the 8-inch space

with the non-conducting material giving the same continuous insulation as at first described in the case of Class A.

The outside wall was of course thoroughly waterproofed by a thick non-odorless coating on the inside, which may be in time followed up by an outside waterproofing.

The floors in this building were 6-inch reinforced concrete or reinforced concrete girders and beams in spans 18 feet by 18 feet.

The insulation of floors was made on top, using either lith or cork board from 2 to 4 inches thick, depending on conditions.

These insulating boards were laid on the floor slab, well "doped" with odorless pitch and waterproofed on top. Over this a 2-inch concrete floor was laid, reinforced with a wire web, and the whole finished off with a half-inch wearing floor of cement and sand rendered waterproof.

Several waterproofing schemes were tried for this wearing floor. Three methods gave good results, but as all are patented processes it would hardly be proper to mention them.

Partitions were of double 4-inch hollow tile with insulating filled space between from 4 to 8 inches.

Again under Class B may be mentioned an exactly similar inside construction as last described which the writer equipped in Detroit.

This is a seven-story building about 150 feet by 170 feet, built on the same lines, except that in the first two stories above ground the outside walls were brick and the walls above of hollow tile, all non-weight carrying and tied to the inside structure as last described.

The floors in the lower part of this building were the regular 6-inch floor slab with reinforced concrete girders and floor beams beneath the floor, while in the upper stories the floors were made of alternate runs of reinforced concrete and tile, the concrete being flush above and below with the tile. This latter presented the same advantage as the Johnson floor, of having no cross floor beams under the floor, making it much easier to run cold air ducts, electric light wires, etc.

Under the Class C of construction comes the cold storage building of the Murphy Storage and Ice Company, of Detroit. The general plans of this building were adopted and the framework was well under way in construction when it was taken hold of by the writer. This was a ten-story building constructed with built-up steel columns and with steel girders running longitudinally with the greatest dimension of the building, the ends of girders resting on the walls, and with I-beams running between the girders and from the girders to the walls on a spacing of a little over 4 feet. The walls

therefore carried their share of the weight of the outside spans. The floors were of a combination tile and concrete.

As the work was already well advanced on this building it was too late to change the construction, and the iron beams were therefore left in the outside spans with a share of the weight carried by the walls. The floors, however, had not been laid, consequently it was possible to stop the prolongation of the floors to the outside wall, and keep them about 8 inches away. Four-inch tile walls were built from floor to ceiling, flush with the edge of this floor, leaving therefore a continuous fill from top to bottom 8 inches thick, excepting where the I-beams ran into the wall at each story on centres of a little over 4 feet.

It was therefore impossible to stop the conduction of heat from the outside wall via the floor beams to the inside of the building; but it was possible to prevent the trouble which has been experienced where steel I-beams have run into the outside wall by reason of the conduction of moisture through the brickwork and running along the cold iron beams into the interior. This was done by carefully wrapping the ends of the I-beams which projected through the 8-inch space between the edge of the floor and the outside wall with hair felt dipped in an odorless compound and making a tight joint with the outside wall.

The inner surfaces of the outside wall were coated continuously from top to bottom with a thick coat of odorless waterproofing material, and the inside 4-inch tile wall was built up in the same manner as described for Classes A and B, and the space between filled with granulated cork.

The columns and I-beams, wherever exposed, were covered with a hollow tile fireproofing, plastered on the outside. That there was some conduction of heat from the interior of the building through the I-beams resting on the walls was evidenced by the fact that before the refrigeration was turned on, and the interior was still warm (at a temperature from 40° to 60°), and after the outside temperature had been very low for ten or fifteen days, and the temperature suddenly rose above the freezing point and the humidity increased to 100 per cent., all of the outside walls frosted, due to the fact that they were cold and could receive no heat from the interior of the building on account of the interposing insulation.

A photograph taken of this building while in this frosted condition showed that there was a distinct line opposite the ends of the I-beams showing less frost than showed on the other portion of the walls. It is not, however, believed that the total conduction from

this source is a very serious matter, although it, of course, counts in the long run. Experience of several months, however, shows that there has been no trouble whatever with conduction of moisture along the I-beams.

In this building the partitions were constructed of double walls of hollow tile with a fill of from 4 to 8 inches of insulating material between, as in the case of the other houses described. The floors were also insulated, as before described, by laying from 2 inches to 4 inches of lith board on the floors, thoroughly "doped" and waterproofed with a 2-inch course of concrete on top, reinforced with wire netting and a finishing course of half an inch of well-trowelled cement and sand.

The floors on all three classes of these buildings were finally waterproofed by a concrete filler and a concrete floor paint presenting a glassy surface, and impervious to water.

In passing it may be mentioned that all of these buildings were refrigerated by the indirect method, using fans and ducts, and dividing the houses up into separate air circuits in which the air was kept in continual circulation by means of fans driving the air over very cheap surfacers which were sprayed with a film of chloride of calcium brine.

All of the storage rooms in these buildings were singularly free from odor, and the air was unusually keen and sweet as compared with buildings constructed with wooden insulation, as all of the surfaces were either of vitrified tile or waterproofed concrete, neither of which absorbs nor gives out odors. It may also be pointed out that the continual passing of the air over the calcium brine surfacers greatly purified the air, as it has been proven that chloride of calcium is quite effective as a germicide.

The researches on this subject conducted by Dr. O. Profe, Dr. Hesse and other German authorities show conclusive results on this point.

In this connection also may be mentioned a fireproof ice storage house of a capacity of about 4,000 tons of ice which was built with an outer wall of three courses of 4-inch vitrified tile, and an inner wall of one course of vitrified tile, the inside course being 8 inches away from the outside wall, and the thrust of the wind pressure without and the ice thrust from within were taken up by running an extra course of 4-inch tile pilaster vertically on 4 feet 6 inch centres, and filling the remaining 4 inches with a vertical course of 4x4 inserted cork board cemented to the 4-inch pilaster and to the outside wall. This made a firm insulated tie between the two walls, and the 8-inch

space between these pilasters and cork ties was filled with granulated cork.

As far as possible the rooms in the warehouses described were so grouped as to place rooms carrying the same temperature one above the other; but where this was impossible, and a lower room had one temperature and the room next above a different temperature, conduction by means of the columns, which were of course continuous, was prevented by insulating the columns in the colder room or the warmer room and joining the insulation of the column with the insulation on the floor, so that no heat could pass from the warmer to the colder room, except by passing through the insulation.

In large houses such as above described under Classes A, B and C it was of course necessary to divide the fire risks into restricted areas to meet the underwriters' requirements. In the case of the building at St. Paul two fire walls were run through the building, dividing it into three fire risks, and in case of the first building described, in Detroit, three fire walls were run, dividing it into four fire risks, and in Class C one fire wall was run, dividing it into two fire risks. These walls were made of double 4-inch tile with a filled insulating space between, and on account of the insulation really produced a much more effective fire stop than a solid wall.

Wherever any openings were necessary double fireproof doors were installed on each side of the wall. The underwriters considered that one of these doors might be a swing refrigerator door, covered with galvanized iron, or tin, in accordance with the underwriters' requirement, and that the other door could be the usual fireproof solid door, normally held open by a fusible link.

Wherever there were openings from the receiving rooms into the refrigerating rooms, vestibules were provided with a fireproof cold storage door on each side of the vestibule. This covered all of the requirements of the underwriters for fireproof construction. All doors throughout all of these buildings, whether refrigerator doors or otherwise, were covered with either galvanized iron or tin in accordance with the underwriters' specifications.

It was ascertained that where buildings were divided into separate fire risks the conduction from one floor risk to the other through the continuous girders could be best avoided by placing the skeleton framework of each fire risk entirely on its own columns instead of using a common column between the two fire risks. This adds very little to the cost of the building and allows a continuous fill of insulating material between each fire risk, and it not only prevents conduction through the columns, but also conduction

is prevented by reason of the insulating fill passing the ends of the floors. It also prevents conduction from one fire risk to the other through the girders. This construction is especially desirable where one floor risk or one section of the whole house is carried on temperatures much lower than the adjoining section.

This general consideration also applies to the elevator shaft-ways, for, if the framing of these shaft-ways is exposed in the elevator shaft, sweating or frosting might be expected from each floor at the framing beams around the elevator shaft. Sufficient allowance therefore should be made to build up a separate tile wall up the elevator shaft, tied at as few points as possible and carrying a continuous fill between this inside wall of the shaft and the tile wall exposed to the refrigerated room.

These buildings, after having been thoroughly inspected by underwriting experts, have been pronounced a very high class risk from a fire standpoint. There are absolutely no openings into the refrigerated rooms except those openings protected by double fireproof doors, and the only openings into the building are at the receiving and delivery rooms; consequently the danger of loss to contents from a general conflagration is greatly minimized, and in fact almost entirely eliminated, and the insulation between the inside and the outside walls lends an additional value to the fire risk.

It has been proven conclusively that almost all of the insulating materials in common use when put up between fireproof walls of tile or brick do not contain sufficient air to support combustion in case of fire playing on the inner or outer wall. Tests have been made by making an opening of good size in the outer wall, exposing the insulation, and building a hot bonfire on the outside immediately against the opening, and continuing the test for several hours. At the end of the test it was found that the insulation was only charred a few inches back from the opening.

Another point may be mentioned which shows the great stability of reinforced concrete construction for beams, girders and a combination of reinforced concrete or tile for floors. In the house mentioned in Class B, at St. Paul, the construction of the concrete work was commenced in the fall and continued through the winter, concrete work being done at temperature as low as 10° above zero by keeping steam on the molds. The refrigeration was turned on in hot weather and the first floors refrigerated were in the centre of the building at very low temperatures, ranging from zero to 5° below zero, with ordinary summer temperatures existing on each side, above and below. Rooms were gradually refrigerated at

various degrees of temperature, ranging from 5° below zero to 35° above. It will readily be seen that under these conditions the building was subjected to the most severe strains that could be conceived of in the way of expansion and contraction, and yet there was not a sign of a flaw or a crack in any column, girder, beam or floor, and this on a comparatively green building, which of course is growing stronger every day.

The proper combination of reinforced concrete, tile, brick and iron will, of course, vary in different localities, depending on the local conditions and the cost of the various materials; but in a general way it may be stated that the cost of the buildings per cubic foot, fully insulated, will run, if anything, less than the cost of a wooden building whether of the ordinary girder or floor beam type, or of mill construction, or of a combination of iron and wood, and that the general method here described of practically constructing the inside of a building with a continuous course of insulation all around has entirely obviated many of the difficulties which might be apprehended in the use of these materials.

The fire risk is also a very important feature, as the first asking rate on these buildings was only 40 cents on contents, which is only about one-third the average rate on wooden or mill constructed buildings, and in some cases one-quarter the rate. As to the buildings themselves the owners as a rule feel that they are practically indestructible and carry their own insurance. Underwriters have offered as low a rate as 18 cents on contents and 5 cents on the building if a sprinkler system were installed. However, until fireproof cold storage warehousees have to enter competition with other fireproof cold storage warehouses it is unnecessary to install the sprinkler system on account of lower rates of insurance, as the rate without the sprinkler system is so far below the ordinary cold storage rate as to render such an installation unnecessary from a competitive standpoint. There is also a feeling that a sprinkler system might do more harm than good in an absolutely fireproof cold storage warehouse, while in a non-fireproof cold storage warehouse its installation has proved to be of practical advantage. The reason for this lies in the fact that in the non-fireproof house a fire starting in one room could easily spread throughout the building if not protected by the sprinkler system, while in a fireproof house, such as described, it would be next to impossible for a fire to extend beyond the room in which it originated.

It must be remembered all the time that a comparison of the fire risk in a fireproof cold storage warehouse with the average

so-called fireproof building is not a fair one on account of the fact that there are practically no openings into the main part of the warehouse, while the average fireproof office building is vulnerable in a general conflagration, owing to the fact that a very large percentage of its outside surface is made up of window openings, and that it is divided into small rooms containing in the doors, trim and other wood work, a large amount of inflammable material. Hence in a general conflagration an office building, although classed as fireproof, may be completely gutted, and even the so-called fireproof portion, such as iron work and the soft tile work, may be damaged from 30 per cent. to 40 per cent.

It would be quite beyond the scope of this paper to touch on all of the points which have to be looked after in the construction of a fireproof cold storage warehouse. There are many apparently small items that cannot be treated here which go to make a fully successful house, but the general principles above set forth of allowing no heat to pass from the outside to the inside, except it passes through the insulation, and similarly no heat to pass from a comparatively high temperature room to a low temperature room without having to pass through insulation at every point, are those adhered to from start to finish.

DISCUSSION.

F. E. Matthews.—I would like to raise the question of expansion and contraction.

John E. Starr.—The cork and bar tie was only used in the construction of an ice storage house. The difference in the temperature outside and the ice expected to be held under refrigeration is not large, and the expansion and contraction of the inside and outside walls are certainly not expected to be enough to damage materially the building or menace its stability. In the main warehouses which I have described the ties between the inside and the outside walls are sliding and flexible. As to the expansion and contraction in a building, I can only say that it appears that the coefficient of the expansion and contraction of the iron reinforcement and the concrete is so nearly the same that under great changes of temperature, such as I have described, no ill results have appeared.

F. E. Matthews.—Could you recommend the cork and bar tie in the case of warehouse construction?

John E. Starr.—No; I should hardly go that far. I do not think I have enough information on the subject. For instance, modern cold storage warehouse construction requires temperatures going

down to 5° below zero, and that is a very different thing from an ice house. I do not think that there has been experience enough to warrant merely the cork and bar tie in a large cold storage warehouse.

F. E. Matthews.—I would like to ask Mr. Starr how he constructed his air ducts in the fireproof system.

John E. Starr.—An answer to your question would almost involve another paper; but, briefly, I may say that all the vertical ducts were constructed of vitrified tile and all of the horizontal ducts were of galvanized iron, all being fireproof. In going over the matter, the Board of Fire Underwriters considered the question of smoke loss by reason of a fire, as there were in some cases three or four rooms on one air circuit, and while it was felt that flame would not pass from room to room, there was some apprehension of loss resulting from smoke being carried from one room to another, and the only method of meeting that difficulty was to employ dampers in each inlet and outlet duct. These were so counterweighted that they would shut automatically, but were held open normally by fusible links, in which a very low temperature of fusion was used; in fact, we have experimented, and think we have got as low as about 50° for the fusible link. This method of closing the dampers seemed to satisfy the fire underwriters completely.

Irving Warner.—Have you had any trouble in the method of indirect cooling, with the air carrying along any dampness by reason of it going through this calcium chloride brine?

John E. Starr.—No; on the contrary, the cold brine, of course, has a double action; it dehydrates the air by reason of its cold temperature, just the same as a cold pipe, the moisture of the air being condensed into the chloride of calcium brine. The latter is chemically an absorbent of moisture. The other trouble that we have experienced is the actual mechanical conveyance under one or two conditions of the brine itself, where the speed of the air was too great and the brine was sprayed too liberally. We had one case of the actual mechanical conveyance of the small particles of calcium brine. We learned something, and after that we had no trouble at all. We had some trouble in Washington Court House and in a small installation in New York. In the three houses in St. Paul and Detroit we had no trouble at all.

John C. Sparks.—In respect to calcium of chloride being practically a germicide, do you not think that any germ in the air is held in the atmospheric moisture?

John E. Starr.—I would not have thought so except for some

literature that I happened to run across on the subject, by a German chemist. I have no accurate knowledge of the matter. I only feel sure that if there was no chemical germicidal action, if it may be so termed, you would expect the air to be clean and pure, anyhow. The German authority I have mentioned went a little further than that and stated that chloride of calcium was a germicide, especially in regard to certain forms of mould and spores, and so forth. I have no way of proving or disproving this statement.

No. 44.

THE BEST METHODS OF DETECTING IMPURITIES IN AMMONIA IN REFRIGERATING PLANTS.

By John C. Sparks, New York, N. Y.

(Associate Member of the Society.)

There are several methods in more or less general use for the determination of impurities in ammonia. The first consists in drawing from a drum of ammonia, or from the liquid receiver in the plant, a quantity of liquefied ammonia into a flask. This liquid ammonia is allowed to evaporate, and any liquid remaining in the flask that will not evaporate at atmospheric temperature is either measured directly, and two-thirds of its volume considered water, or else it is reserved for more careful examination.

This method will show the percentage of matter that cannot be evaporated, and is of value in determining water.

One of the impurities that cause most trouble in a refrigerating machine is an incondensable gas, the result of too high temperatures. In a plant which contains in its system an appreciable quantity of these gases the effect produced is very marked. The high pressure is much increased and the economy of the plant reduced.

I have found, taking the ordinary tables of the properties of ammonia, finding the temperature of the cooling water going over the ammonia condensers, and comparing this temperature, allowing 10° for transmission, that if the high pressure gauge shows a higher figure than would correspond to a water 10° warmer than the actual temperature of the cooling water, there is a measurable quantity of incondensable gas present in the ammonia. This gas collects at any high points in the system, and one of the best points to make a test is from a point at the top of the ammonia condensers. A small expansion valve, followed by a pet cock, may be placed at the highest point possible and be used for drawing off the gas.

The general theory of the formation of such gases presupposes that the ammonia has been dissociated and has undergone some change. The result of such action produces gases which are insoluble in water. By allowing the gas to come off very slowly and being passed through a large volume of cold water, which will absorb all the ammonia present, only the foreign gas will be collected.

The following method requires no special skill and may be used as a test to determine if there is any incondensable gas in the system. Get an ordinary glass gas collector, which consists of a glass cylinder, closed at each end by a glass cock. Fill it absolutely full with water. Attach a short piece of rubber tubing, the shorter the better, to the pet cock and to one entrance of the gas collector. Hang up in a vertical position and open the expansion cock very little, the pet cock slightly, and very slowly turn the upper glass cock. Gas will enter and drive some of the water out. When the collector is one-third full of gas shut the top cock and leave the bottom cock open. This will equalize the pressure and more water will run out. Wait till no more comes out, and then close the bottom cock. This usually leaves about one-third of the original water still in the collector.

Now disconnect the tubing from the upper cock and agitate the water in the collector. If there is much ammonia in the gas this will be absorbed, so the collector should be placed in a basin of water. With the lower cock under water, open this cock. Water will be sucked into the collector to take the place of the absorbed ammonia. When no more water enters close the cock and remove from the water.

This operation of absorbing the gas in water should be done two or three separate times, following the same routine, and after this has been done the remaining gas is evidently not ammonia and can be studied.

This operation is quite simple and can be done with great accuracy if care is taken to expel all air from the connecting tube, which is quite short, by waiting almost a minute after it is first slowly turned on. Only one precaution need be emphasized. The gas coming into the collector is under high pressure, so it should only be allowed to come in very slowly and the inlet turned off when one-third full. There is always some ammonia in the gas, and the rapidity with which this is absorbed by the water helps to cut down the pressure.

This simple test will show in a very few minutes if there is any incondensable gas in the system, and any operating engineer can easily do it.

The examination of the unabsorbed gas, when obtained, is usually not necessary, but it can readily be determined if this gas is air or due to dissociation of the ammonia by allowing it to pass into an absorber containing a solution of pyrogallic acid in potassium hydrate. If one-fifth of the gas is absorbed by this solution the gas

is air. I do not lay any particular stress on this special test, as it is not usual to find any air in the system.

In regard to any further impurities that may be in the ammonia, there is very rarely a light yellow oil, which shows itself on making the evaporation test referred to above.

This subject does not call for much explanation in regard to the manner of making the tests. It is only the tests of a simple, practical nature, which can be made at the plant, which I am considering in this paper.

In regard to the value of the tests when made I have found them of distinct use in helping to find why there is poor economy in refrigerating plants.

I have made several examinations in plants which showed poor economy, and have found incondensable gases in conjunction with abnormally high head pressure.

DISCUSSION.

Albert A. Cary.—Does Mr. Sparks use the regular 250-cubic centimetre collecting bottle?

John C. Sparks.—No; I use a 5-cubic metre bottle. A small size is no good, because in the course of events you get much more ammonia than anything else, and in nearly every case you find that when you start the absorption of the gas the whole volume will be absorbed, showing that there is nothing but ammonia in the system.

Gardner T. Voorhees.—A question that has come to me a great many times, one regarding which I have heard a great many and various opinions, and one that costs a good deal of money, is: Does ammonia in an absorption machine disintegrate more rapidly when the original charge is strengthened from time to time with anhydrous ammonia than when it is strengthened with aqua ammonia, and if so, why?

John C. Sparks.—Personally I have had no experience on that particular point. I do not see why it should. In my mind there is no reason why it should.

Guy B. Smith.—At what temperature does ammonia decompose?

John C. Sparks.—There is a partial decomposition in the presence of oil and iron at a very much lower temperature than ammonia decomposes by itself; it will decompose at a temperature of from 350° Fahr. up under those conditions, but ammonia by itself will not decompose at that temperature.

Chairman Wills.—At what temperature will ammonia decompose by itself?

John C. Sparks.—At 700° Fahr. There is a variety of figures, some as high as 800° or 900°, but ammonia in conjunction with oil decomposes at a lower temperature. It depends entirely upon the quantity of oil and the conditions.

Albert A. Cary.—I would like to ask Mr. Sparks about what pressure will be obtained in the gas-collecting bottle, collecting as he has described, and what he considers a safe limit of pressure when using this bottle. If too high a temperature is obtained, the bottle may explode and injure the operator.

John C. Sparks.—The gas collector is open at the bottom and the gas is allowed to come in very slowly, so that the pressure is being cut down by that means all the time. The gas is, besides, largely ammonia and is being absorbed by the water, which also keeps down the pressure. If you fill the gas collector one-third full, you will find that there is no great pressure; it will not force it down more than half full, and there is no danger of undue pressure at all, because the latter is taken up by the absorption of the ammonia in the water, and by the upper cock being open.

Thomas Shipley.—Are we to understand, Mr. Sparks, that ammonia will not decompose unless it is subject to a heat above 350°, even if it is subject to contact with oil?

John C. Sparks.—In an experiment I tried I found that it did not.

Thomas Shipley.—There was no decomposition at all?

John C. Sparks.—None whatever.

Thomas Shipley.—No matter if it was in contact with oil?

John C. Sparks.—I had it in contact with oil and iron.

Thomas Shipley.—It did not decompose?

John C. Sparks.—I did not get any; no.

R. L. Shipman.—I notice that you state that the foreign gases are lighter than ammonia.

John C. Sparks.—No.

R. L. Shipman.—I believe you will find that air is heavier than ammonia.

John C. Sparks.—I stated that the uncondensable gases would be at the highest point.

R. L. Shipman.—For what reason?

John C. Sparks.—Let us figure it out—everything that is condensable will be in the lower part of the condenser and, therefore,

the uncondensable part should be found in the upper part of the condenser.

R. L. Shipman.—Naturally all uncondensable gas would get ahead of the ammonia, and whether heavier or lighter it would be forced to the bottom of the condenser by the current of the condensing vapor.

John C. Sparks.—I am not quite sure of the specific gravity.

R. L. Shipman.—It is about the same as steam; half of that of air, I should say.

Albert Johnson.—Will Mr. Sparks tell us in what manner he heated this ammonia and how he made the test for decomposition; what sort of a test was it?

John C. Sparks.—I had a circulating coil that was in an oil bath the temperature of which could be regulated, and I had the gas that came off from that coil absorbed in water. I found that at anything below 350° I got all my gas absorbed. Any gas resulting from the splitting up of ammonia will not be soluble in water, so I could figure that any I obtained that was soluble in water was ammonia.

H. Dannenbaum.—I believe that in an absorption system the formation of non-condensable gases is due more to the decomposition of water than to the decomposition of ammonia. This is readily proven by the fact that if at the end of a year you clean out an absorption still you will always find a certain amount of various oxides of iron. Now, ammonia does not contain oxygen, and for that reason it is impossible that the oxygen could originate from the ammonia. If you analyze the foul gas in an absorption system I believe you will find that it is mostly hydrogen. Hydrogen burns very readily, with a bluish flame, and that, of course, explains the presence of a burnable foul gas. The quality of the iron has undoubtedly something to do with the decomposition of the water, and it may be caused by galvanic currents. Just what causes the decomposition is difficult to say, but for reasons stated I believe it is a decomposition of water.

John E. Starr.—I quite agree with Mr. Dannenbaum, but in addition to his reason for the possibility of the splitting up of the water I think it can be proven beyond any question, by anyone who has had any large experience with absorption machines, that the splitting up of the water and the consequent oxidization of the coils in the still and perhaps in the exchanger, accompanied by the presence of large amounts of hydrogen gas in the condenser, always increases with the increase of the temperature of the steam;

that is to say, if you are running an absorption plant with comparatively low temperatures of steam, where the temperatures of ammonia are comparatively low, say due to 20 or 30 and not to exceed 40 pounds of steam, you will not find heavy oxidization on the coils, on the exchanger or generator, or the presence of so large a quantity of hydrogen in the condenser. But in every case that has come under my notice, where a machine has been so designed that high pressure steam, say 80 pounds, had to be used, there was a very heavy oxidization of the coils in the generator, and an accumulation of gas, mostly hydrogen, in the condenser, so much so that in cases where they used 90 pounds of steam the condenser had to be cleaned out about three times a day in order to get the machine to run at all. I think the temperature under which the machine is operated has a good deal to do with the matter.

Gardner T. Voorhees.—I did not get an answer to my question. I wanted to see if I could get someone to say something about it. I have talked with a great many engineers, and they said that they would put so many drums of anhydrous ammonia into a machine and it would pick up and do fine work for two or three days or a week, and then would go right back, although it seemed to have the same amount of charge. Some of the engineers thought it was due to the charging with anhydrous ammonia. I wish I could get some of the absorption machine men to say whether they had had that experience; I am looking for information.

John E. Starr.—In reply to Mr. Voorhees's question, I think that if every case had been investigated where the action was such as has been described it would have been found that the falling off in the efficiency of the machine was due to the accumulation of hydrogen gas in the condenser. An absorption machine is a very different proposition from a compression machine. The moment you begin to fill up the condenser of an absorption machine with non-condensable gas, and yet have apparently plenty of surface, then the efficiency of the machine begins to drop. I have seen cases where the entire condenser was cold from top to bottom, showing that practically no ammonia gas was entering, simply because it was full of non-condensable gas, and, in partial answer to Mr. Voorhees's question, my own belief is that the troubles which he mentions do not arise so much from the so-called "burning up" of the ammonia, or from the machine being recharged with anhydrous ammonia or aqua ammonia, as from the fact that in the operation of the machine by the use of high temperature steam the condenser and other parts of the absorber are simply practically put out of business.

I do not now recall a case that has come under my observation where there was an alleged "burning up" of the ammonia, but that it could be traced either to leaks or to the sources that I have mentioned.

Albert Johnson.—In reply to Mr. Voorhees's question I cannot see why the adding of sulphate-made anhydrous ammonia to an absorption plant would not be better than adding aqua ammonia, since the latter is composed largely of water, while the former is absolutely pure. When he adds anhydrous to his system he adds something so pure that he cannot get anything purer. If he adds aqua he adds 70 or 75 per cent. of water and only 20 or 25 per cent. of gas. Most of the largest absorption plants are being charged nowadays entirely with anhydrous ammonia, and aqua is not being used for replenishing at all.

Chairman Wills.—If it is true that the water is decomposed into hydrogen gas, that would reduce the quantity of water, and why would it not require replenishing—that is, why should you keep on putting in nothing but anhydrous? If it is true that the water is decomposed into hydrogen gas, would it not reduce the quantity of water necessary for absorption, which would have to be replaced?

Albert Johnson.—You probably could, but very slowly.

Gardner T. Voorhees.—I was talking to an operating engineer, and he said that if he charged his machine with anhydrous it would not work well; but if charged with aqua it would work splendidly.

Henry Vogt.—We recharge with anhydrous all the time. We have no such trouble, and I rather think that operating engineers lack experience when they make such statements. I am sure that the question has been fully answered by Mr. Starr.

Albert Johnson.—Referring to the so-called decomposition of ammonia by heat, I have visited a great many plants in this country and operated one, and have watched that matter rather closely, and I can say from my observation and experience that I believe ordinary anhydrous will decompose gradually at about anywhere from 300° and up. As the heat is increased the decomposition is accelerated, until when it reaches 700° the ammonia separates at once. In any system in which the discharge gases run from 300° to 350° there will always be slow disintegration.

R. L. Shipman.—I have had some experience with high temperature of ammonia, from 300° to 400°, and if we had had any rapid decomposition we would have gotten our system blocked up from that cause. We have never had any such effect, and we have run at 300° by the month.

No. 45.

THE COMPARISON OF BIDS FOR ICE-MAKING AND REFRIGERATING MACHINERY.

By Thomas Shipley, York, Pa.

(Member of the Society.)

When bids are tendered for the furnishing of ice-making or refrigerating machinery their comparison with a view to determine which bid is the best one for the purchaser to accept is quite a task and requires not only a general knowledge of such machinery and the problems involved, but also a thorough knowledge of the machinery offered by each bidder.

The usual way of tabulating the sizes and dimensions of the principal parts of the apparatus specified by each bidder is all right so far as it goes, but it does not go far enough. The bids should be analyzed and each part of the apparatus should be appraised at its real worth to the purchaser.

Where compression machines are specified the compressors cannot be valued by taking the bore and stroke as the measure of value. The efficiency of the compressor—that is, its capacity for doing useful work per horse power used by the engine or motor which drives it—should be determined. This is the true measure of its value to a purchaser. Due consideration must also be given to its mechanical design to insure its ability to stand up to the work for which it is to be used.

The engine which drives the compressor should be proportioned to suit the efficiency of the compressor it is to drive, for the lower the efficiency of a compressor the lower will be its mean effective pressure, and, consequently, the smaller will be the engine required to drive it.

Where absorption machines are specified the measure of their values cannot be gauged by the square feet of heating surface in the stills, nor the cooling surface in the absorber, nor of any other part of the apparatus. The efficiency of the apparatus as a whole—to do a unit of work with a given amount of steam within a certain range of pressures and with a certain amount of cooling water—

should be determined. This is the true measure of its value to the purchaser.

Consideration must also be given to the design to insure continuous operation and accessibility for repairs and renewals. It is necessary to know all the conditions under which an absorption machine is to be operated before even an approximate value can be put upon it.

Ammonia condensers cannot be compared by taking into account only the number of coils or stands which the bidder specifies he will furnish. The efficiency per square foot of surface must be taken as their measure of value. The number of British thermal units absorbed by the condensing water per square foot of surface per hour for each degree of mean difference in temperature between the ammonia to be condensed and the condensing water is the item which determines the economy of the apparatus and decides its value to the purchaser.

The material to be used, the design of the apparatus and the connections to be furnished between each coil or stand of the apparatus itself, as well as the connections between the apparatus as a whole and the other parts of the plant, must all be known and be taken into account in determining the values. The temperature, quantity and quality of the condensing water available must be taken into consideration in determining the value of ammonia condensers.

In the evaporating system the number of feet of coil surface which a bidder specifies he will furnish is not the measure of value of the apparatus. It is the heat which each square foot will absorb per degree difference in mean temperature which is the measure of value. Each part of the system must be properly connected up to the other parts of same, and the system as a whole must be properly connected to the other parts of the plant. The system must be proportioned to suit the ammonia compressor to which it is to be connected.

In a can ice plant the number of cans per ton is not the measure by which to decide the value of the bidder's proposition. It is the efficiency of the can surface—the amount of ice that each can will turn out in a given time—which determines the value per can. The exact size of the cans, with the weight per can, should be taken into consideration in the measure of value to the purchaser.

It is the same with every detail which goes to make up a plant. The measure of value is the efficiency of that detail and not its size, length or number. The more compact and simple a plant is, consist-

ent with durability and cost of operation, the more valuable it is to the purchaser.

The question will be asked, Who is to decide these technical questions? The average purchaser certainly is not capable of making a decision himself, because of his lack of knowledge. This is true, and it is also true that unless the purchaser is a competent engineer he should secure the services of an engineer who is competent to advise him.

It is certainly a good business proposition for a purchaser to consult a competent engineer concerning questions which it is not safe for him to decide from his own knowledge. The investment he is about to make is a large one and a mistake would be costly. How easily a mistake can be made, even when every precaution has been taken, is known to everyone who has had anything to do with this class of machinery.

The following will give an idea of some of the causes of the mistakes which are made in the comparison of bids by men who are not experts in this class of machinery.

In comparing bids for compression machinery little or no attention is paid to the matter of clearance in the compressor or whether the valves have sufficient area and are properly balanced, or whether the inlet connections are so made that they will allow the gas to enter the compressor without unnecessary loss in pressure, thereby reducing the value of the compressor. The low efficiency compressor is taken at the same value as the one which has a high efficiency.

The question of wet and dry compression is passed over as if it had nothing to do with the value of the compressor, and the matter of horse power per ton of refrigeration is usually not discussed or considered at all.

The fact that a wet compression machine of a certain dimension will require a smaller engine to drive it than is required to drive a dry compression machine of the same dimensions has been used to lead purchasers to believe that the wet compression machines are the most economical, when the reverse is the fact, for the reason that a dry compression machine will do about 40 per cent. more work than a wet compression machine of the same dimensions, and do this work at a much less expenditure of power per ton. Tables I and II will illustrate this more clearly. In these tables a comparison is made between three machines. The vertical single-acting machine of 100 tons refrigerating capacity is taken as the basis.

The wet compression machines are assumed to have 70 per cent.

volumetric efficiency when operating under dry compression conditions. Should the efficiency be below this the capacity would be reduced and the horse power per ton would be increased and a larger engine would be required to operate the compressor.

TABLE I.

Comparative Amount of Work that can be done by 18x28 inch Compressors under the Conditions Stated and the Size and Horse Power of the Steam Engine Needed to Drive each Machine.

Condition.	Type Machine.	Compressor.				Engine.		
		No.	Size.	Volumetric Efficiency. Per Cent.	Tons Refrigeration.	Size.	I. H. P.	H. P. Per Ton.
Dry Comp.	Vertical S. A.....	2	18×28	80	100	26 ×28	170	1.7
Dry Comp.	Horiz. D. A.....	1	18×28	70	88	26 ×28	171.6	1.95
Wet Comp.	Horiz. D. A.....	1	18×28	..	64	25¾ ×28	167	2.61

TABLE II.

Comparative Size of Compressor Required to Do 100 Tons of Refrigeration under the Conditions Stated, also the Size and Horse Power of Engine Needed to Drive each Machine.

Condition.	Type Machine.	Compressor.				Engine.		
		No.	Size.	Volumetric Efficiency. Per Cent.	Tons Refrigeration.	Size.	I. H. P.	H. P. Per Ton.
Dry Comp.	Vertical S. A....	2	18 ×28	80	100	26 ×28	170	1.7
Dry Comp.	Horiz. D. A.....	1	19½×28	70	100	28 ×28	195	1.95
Wet Comp.	Horiz. D. A.....	1	22½×28	..	100	32¼×28	261	2.61

Conditions: 15.67 pounds suction pressure; 185 pounds discharge pressure; no liquid cooling; one-quarter cut-off in steam cylinder; 90 pounds steam pressure; 59 revolutions per minute.

The stroke of both the compressors and engines in the above tables is kept constant, so as to emphasize the difference made by operating a compressor under the conditions stated.

The tables show that the value of a compressor to a purchaser cannot be judged by its size, and the man who attempts to decide

without knowing the true value of the compressors offered is likely to make a costly mistake.

The different types of ammonia condensers have their particular values, which must be known to be able to judge which is the most suitable for the purpose required by a purchaser. A full knowledge of all the conditions under which the condenser will be operated is needed before a decision is possible. The atmospheric and double-pipe types of condensers are the ones most generally used.

So far as I know, there have been no tests made on the atmospheric type of condenser which establish the value of a square foot of condensing surface through the various conditions met with in the use of this class of apparatus. A safe allowance is 20 square feet per ton, with water ranging between 60° and 70° Fahr.; but a flat allowance per ton is not a good measure of value, for the reason that different conditions need different treatment.

If water is scarce, the condenser surface must be made to suit. If the temperature of the water is high, provision must be made for that condition. If the water has a low temperature, then advantage should be taken of that fact. If the water is of such a nature that it deposits scale or slime upon the condensing surface, a different allowance of surface per ton must be taken to provide for this condition. If first cost is more important than economy, then it requires a different layout than if economy was desired.

The tests made at York, Pa., on the double-pipe condensers brought out a great many facts concerning the value of a square foot of condensing surface under different conditions. To illustrate this and to show what a range of knowledge is required to decide upon the value of condensing surface, I call to your attention some of the data we obtained. I also desire to remind you that these data relate only to 70° condensing water, and that the values given will not be true for any other temperature or condition than those stated.

The following tables show the effect of increasing the condensing water passing through a double-pipe condenser.

Such tables as Nos. III and IV enable the expert to determine the size of the condenser which will be needed to do certain work. If capacity is the requirement, Table III shows what can be done and what the cost in power will be. If a reduction in horse power is the requirement, Table IV shows how to obtain it and at what expense. These tables also show how to economize in water, and what the corresponding loss in capacity will be.

To arrive at the value of an evaporating system requires a full

Tables III and IV.

Capacities and Horse Power per Ton Refrigeration of One Section Counter-Current Double-Pipe Condenser, 1¼-inch and 2-inch pipe, 12 pipes high, 19 feet outside water bends, for water velocities 100 to 400 feet per minute; initial temperature of condensing water 70° Fahr.

Table III—High Pressure Constant.

Condensing Water.				Capacity in Tons Refrigeration Per Twenty-four Hours.	Condensing Pressure Pounds Per Square Inch.	Horse Power Per Ton of Refrigeration.		
Velocity Through 1¼-Inch Pipe. Feet Per Minute.	Total Gallons Used Per Minute.	Gallons Per Minute Per Ton Refrigeration.	Friction Through Coil. Pounds Per Square Inch.			Engine Driving Compressor.	Circulating Water Through Condenser.	Total Engine and Water Circulation.
100	7.77	1.16	2.28	6.7	185	1.71	0.0016	1.7116
150	11.65	1.165	5.75	10.	185	1.71	0.004	1.714
200	15.54	1.165	9.98	13.4	185	1.71	0.007	1.717
250	19.42	1.18	15.	16.4	185	1.71	0.011	1.721
300	23.31	1.24	21.6	18.8	185	1.71	0.016	1.726
400	31.08	1.30	37.8	24.	185	1.71	0.030	1.74

Table IV—Capacity Constant.

100	7.77	0.777	2.28	10.	225	2.04	0.001	2.041
150	11.65	1.165	5.75	10.	185	1.71	0.004	1.714
200	15.54	1.554	9.98	10.	165	1.54	0.009	1.549
250	19.42	1.942	15.	10.	155	1.46	0.018	1.478
300	23.31	2.331	21.6	10.	148	1.40	0.030	1.43
400	31.08	3.108	37.8	10.	140	1.33	0.071	1.401

Notes—Above tables are based on the heat transmission obtained for various velocities of water, as averaged up from the York Manufacturing Company's tests on double-pipe condensers.

The horse power per ton is for single-acting compressor and 15.67 pounds suction pressure.

The friction in water pump and connections should be added to water horse power and to total horse power.

knowledge of how that system is to be connected up and operated.

An expansion system, or one where the ammonia leaves the coils slightly superheated, requires about 33⅓ per cent. more pipe surface than a wet compression system, which is a system where the ammonia leaves the coils containing sufficient entrained liquid to maintain a wet compression condition in the compressor.

The flooded system is one where the ammonia is allowed to flow through the coils and into a trap where the gas is separated from

the liquid, the gas passing on to the compressor, while the liquid goes around through the coils again, together with the fresh liquid which is fed into the trap. Such a system requires only about half the evaporating surface that an expansion system does to do the same work.

Hence, if a purchaser buys his evaporating system on the foot basis, without knowing how the system is to be used, he is likely to get into trouble, or lose money by buying too large a system for his work.

The main connections between the different parts of the plant should have very careful consideration, as the successful operation of many plants is interfered with very materially because they are not properly connected up.

Small and exposed suction mains are a source of much trouble. The ammonia receiver and liquid ammonia connections are another drawback to many plants, no care being taken to keep the temperature of the liquid ammonia as low as possible. Placing an ammonia receiver in an engine room may look very nice, but it is in the same line as running your distilled water mains through the furnace under your boilers. It simply evaporates part of the liquid and drives gas back into the condenser to be recondensed. Such connections make it necessary to use larger condensers and more condensing water, and, in addition, the liquid ammonia goes into the evaporating system carrying the full quota of heat, thereby reducing its value to a minimum.

These are things a purchaser knows nothing about, unless he has been through the mill and has taken an active interest in the operation of his plant. A buyer can get a cheaper plant by allowing the connections to be slighted, but he pays for it over and over again until he has the trouble corrected.

The average purchaser believes that the most desirable proposition is the one which will give him the largest size compressor and the greatest number of feet of pipe in the various parts of the apparatus for the least money. He does not know that possibly a smaller compressor and a much less number of feet of piping will do more work and will do it for less cost than the larger apparatus. He does not consider that the smaller the plant he has to put in to do his work the less will be his expense for buildings, and that the real measure of value to him is the total cost of his plant, including not only the machinery but also the ground, buildings, foundations and everything that is required to make his plant operative.

Take a compression ice plant, for instance. Some designs require that the ammonia condensers be placed 40 or 50 feet above the freezing tank level, so that the water used on the ammonia condensers will flow by gravity to the steam condensers, and that the distilled water will flow into the reboiler, the reboiler being high enough to give a static pressure sufficient to drive the distilled water through the purifying apparatus into the storage tank, which in turn must be high enough above the freezing tank to allow the water in it to flow to the ice cans. This looks innocent enough to the man who does not know what it means in the way of expensive building construction and the cost of pumping the condensing water to the top of the ammonia condensers. Twenty years ago this was considered good practice, but it is not the best practice today.

It means a cheaper price for the machinery of the plant, but the purchaser pays many times the amount he saves on the machinery account in the additional money he must spend on his buildings, and then he is at a continual additional expense in operating the plant.

The compressor must be of high efficiency and should be driven by an engine which will give the greatest average economy, and not one which will give a high economy at the peak of the load and a low economy at all other times. The peak of the load is only met occasionally, and the engines would better be overloaded at that time, so as to give a better average economy throughout the season's run.

If the amount of steam used to drive the compressor is not kept down to a minimum the consumption for this purpose alone will exceed the total amount needed to make distilled water enough to fill the ice cans; hence when the steam consumption of the auxiliaries is added the coal consumption per ton of ice made will be excessive. This surely does not mean that the cheapest machine is the best investment, even in a can ice plant.

When it comes to the freezing system, the amount of surface in the evaporating coils depends on the way they are connected up and the manner in which the ammonia is to be used in them.

The purchaser who is not familiar with the facts relating to the difference in value existing between the expansion, the wet compression and the flooded evaporating systems is certainly at a loss to decide what amount of evaporating coils is sufficient for his work, or to satisfy himself as to the relative values of the bids he has received. The three systems—expansion, flooded and wet compression —will be proportioned about as follows:

A dry compression plant with an expansion evaporating system

will need a medium size compressor, a large size evaporating system and a small amount of ammonia.

A dry compression plant, with a flooded evaporating system, will need a small size compressor, a small size evaporating system, and a large amount of ammonia.

A wet compression plant, with a wet compression evaporating system, will need a large size compressor, a medium size evaporating system, and a medium amount of ammonia.

The number of cans per ton depends upon the temperature at which the freezing is done and the temperature of the distilled water entering the cans; hence the number of cans cannot be taken as the measure of value, for if the work is not done in the freezing tank it must be done elsewhere, and apparatus must be furnished to do this work, and as this apparatus takes the place of a certain number of cans it should be taken into account when a comparison is made.

A large number of cans allows a higher temperature to be carried in the freezing tank. This means a higher back pressure, which in turn means the requirement of a smaller or less efficient compressor. It also means less apparatus in the distilling and purifying system, as well as less apparatus to cool the water before it enters the cans; hence a large number of cans are put in at the expense of other parts of the apparatus, for unless this is the fact there is no need of the extra number of cans.

It is false economy to put in a badly balanced plant. Each part of the plant should be able to do its work with a reasonable factor of safety. Having every part of the plant on the same basis should reduce the total investment to a minimum, and such a plant will pay the largest dividends.

If you want a plant to produce 50 tons of ice per day it is not economy to put in a 75-ton compressor, for it will have to be operated at a considerable loss to be run at 50 tons capacity. The investment is the same as if you were making 75 tons of ice, and so are the wear and tear and the amount to be charged off each year for depreciation; hence, unless it is the intention to increase the plant to the full capacity of the compressor within a year or two, it is a better investment to put in a compressor that will be operated up to its normal capacity. It is the same with any other part of the plant that is too large for the work that is to be done.

The less number of cans there is in a freezing system per ton of ice the more valuable the freezing system is to a purchaser, for such a system requires less building, less foundations, less insulation and less work to harvest the ice.

It would require a very lengthy paper to cover the entire ground, showing why it is good policy to have bids for this class of machinery compared in a proper manner by men who are competent to do such work; hence I have not attempted to take up the details of different types of plants and apparatus, but have tried to bring to your attention a few items to show the necessity of thorough knowledge of the machinery about to be purchased, and that there is a certain amount of knowledge needed before a man is competent to analyze such bids.

Some of you may question the propriety of reading a paper like this before a meeting of engineers, as it contains more advice to the purchaser than to the engineer. However that may be, if what this paper contains reaches some of you who are aspiring to become competent engineers in this line of business, and who, as yet, have not had the opportunity to acquire the knowledge suggested in this paper, and by reason of these suggestions you proceed to and do obtain such knowledge before you class yourself as an expert, then it has not been read before this convention in vain, and both the purchaser who employs you and the manufacturer with whom you come in contact will be greatly benefited.

DISCUSSION.

Louis Block.—Mr. Shipley, you said in your paper that the difference in efficiency would be 40 per cent.?

Thomas Shipley.—I did.

Louis Block.—Will you explain what wet compression is?

Thomas Shipley.—Wet compression is where the discharge gas leaves the compressor at the point of saturation due to the high pressure.

Louis Block.—At the temperature which is due to saturation?

Thomas Shipley.—Yes.

Louis Block.—Since there is no way of determining whether you have put in more liquid feed than is necessary to keep the gas at that temperature, it is really an uncertain quantity.

Thomas Shipley.—I claim that it is impossible to put sufficient ammonia into a compressor to maintain those conditions, as it does not evaporate quickly.

Louis Block.—Suppose you have a condenser pressure, as you have stated, of 185 pounds, and your discharge temperature was 140° to 145°, yet you would permit gas to enter the compressor at the point of saturation. What would be the mechanical result of such a pressure?

Thomas Shipley.—If you have 140° you are not running wet compression.

Louis Block.—You determine the wet compression by the discharge temperature?

Thomas Shipley.—Yes.

Louis Block.—I had a talk with Professor Linde early last spring, and I asked him whether he continued to let the gas come back to the compressor so wet that his discharge temperature was that which is due to saturation, and he replied in the negative; he had given up that long ago, and that the discharge temperatures were now between 140° and 150°. I told him I was glad to hear he had come to that.

Thomas Shipley.—If Professor Linde can hold a discharge temperature of 140° to 150° with 185 pounds condensing pressure, he is doing something we could never do, for as soon as the suction gas reaches the temperature due to the back pressure there is no way of telling how much liquid is entering the compressor, and the discharge temperature jumps from one point to another through a range of over 100°. This is our experience in more than 200 tests.

Louis Block.—He meant that the gas came back to the compressor at saturation, not superheated, and that the discharge temperature was about 140° to 150°. Whether it goes to 170° or down to 130° would not make very much difference, as long as it reaches the compressor with the gas at saturation.

Thomas Shipley.—If the suction gas reaches the compressor with the gas at saturation without entrained liquid, his temperature will be 200° or more.

Louis Block.—There will be some entrained liquid, but there will not be any liquid to re-expand.

Thomas Shipley.—Of course entrained liquid will not jump into gas instantaneously, as you know it takes time for it to evaporate, even when it is placed on a steam cylinder and in contact with a temperature of 300°.

Louis Block.—During the compression period it is, I think.

Thomas Shipley.—Some of it will be evaporated, but it takes time to evaporate it.

Louis Block.—The discharge temperature of the gas would show you whether there is too much liquid ammonia in it. If your discharge temperature is 140° or 150° you can easily assume that there is no liquid in the compressor.

Thomas Shipley.—I believe it is practically impossible, even on

a test plant, to regulate the amount of liquid ammonia entering a compressor so as to keep the temperature of the discharge gas at any specified point between that due to the suction gas being dry and where it contains sufficient entrained liquid to keep the discharge gas temperature down to the point where it is condensing. I have tried to do this, and have had some mighty good men try to do it, but I never accomplished it, nor have I seen anyone else do it. You may remember that I was with the Wood & Richmond Company when it tried to do this by putting spraying nozzles into each end of double-acting compressors, the ammonia being injected when the piston was on the compression stroke. After the failure of that company the De La Vergne Machine Company, with which you were at that time, bought up the patents. Mr. Wood and myself, under the name of Wood & Shipley, continued the business, and we tried to do the same thing by using an injection or spraying nozzle in the suction pipe just as it entered the compressors. We did not make a success of the business, and failed, too, and the patents we had gotten out and were working under were also bought up by the De La Vergne Company; so, you see, I had some bitter experiences with machines having compressors cooled by liquid ammonia.

Louis Block.—I have had always the best service out of a compressor when the gas came to the compressor at the point of saturation.

Thomas Shipley.—Yes.

Louis Block.—Never mind what the discharge temperature might be.

Thomas Shipley.—Yes.

Louis Block.—That might more or less affect the horse power, but it does not affect the capacity of the compressor.

Thomas Shipley.—Yes.

Louis Block.—You have evidently tried different condensers, but have you ever tried the efficiency of the De La Vergne condenser?

Thomas Shipley.—I have taken off the liquid drain pipes of the De La Vergne condensers and reversed the gas connection, putting the gas in at the top and taking the liquid out of the bottom in the ordinary way, and increased their capacity, but I have never investigated the cause of this practical increase of capacity.

Louis Block.—You stated that 20 square feet of condenser surface per ton of refrigeration was about right. I have a large amount of data of tests of the De La Vergne condensers, which all had a surface of 17½ square feet per ton, and they did the work

admirably. We started building very high condensers, fifty pipes high, but it was to determine how much lower a condenser might be built and still do its duty efficiently, which brought us to make these tests. The result was that we found we could make as low as eighteen pipes high, but preferred twenty-four pipes high, in order to meet every condition of water. Seventeen and a half square feet of surface per ton for these condensers has always been sufficient.

Thomas Shipley.—Yes, if you can get the water to lie close; but if the water jumps off the condenser and leaves a dry spot you lose efficiency.

Louis Block.—That is necessary.

Thomas Shipley.—The water must be kept evenly distributed all the time and the coil surface covered.

Louis Block.—The condenser must be kept clean.

Thomas Shipley.—There is where the economical and practical part comes in. You have to put enough surface in the condenser to take care of the dirty conditions.

Louis Block.—For 90° water I was always in favor of increasing and did increase the condensing surface; but we do not object to water anywhere from 54° to 70°.

Thomas Shipley.—The difficulty of testing a surface condenser is that in a practical plant you go on day by day and a film of scum comes over the pipe if there is any dirt in the air or impurities contained in the water used. That is why you cannot go too close to theoretical conditions, whereas in the double-pipe condensers you do not have the atmospheric conditions to contend with to such an extent, and you are not bothered so much by impurities in the condensing water. I find it hard to determine the best practice. You can determine the value of the surface under the conditions in which you are operating; but it is hard to set a hard and fast rule for running conditions, and I would advise that surface condensers be kept liberally proportioned.

I want to call your attention to one or two things in connection with the paper I have read. A little knowledge is dangerous, as President Jacobus told us in his address, and to illustrate how this applies to our business I would refer you to the paper read by Mr. Warner. That paper contains certain data which no doubt some of you have down in your note books. The reason why I asked Mr. Warner to explain about the conditions under which that freezing system was being operated was to keep you from following up the error of most of us old fellows in the past. You know we used to go

around and pick up data like that, without knowing the conditions under which a plant was being operated, and put them in our little books, and possibly get into trouble by attempting to get similar results under other conditions.

From the sketch that Mr. Warner made you can see the way that apparatus was being operated; that the back pressure he mentions in his paper is only the pressure at the machines, and there is a vast difference between that pressure and that at which the freezing system is being operated.

In the first place, he shows where he starts the ammonia into the system through number one plate, and then it carries through to number two, three and four, and some of the sections having more than four plates, and then into the suction pipe; and he also shows the choke valve where he chokes the pressure 2 or 3 pounds, and then it goes into another series of coils and passes into the pipes in the storage tanks, and afterward into the machine.

If any of you gentlemen go to work and figure that freezing surface, and try to make some sort of a curve as to the conditions under which the freezing surface is working, you will have to determine what the temperatures are inside. That is a point which is not given, and before you can use the data in Mr. Warner's paper for any practical purpose you must know the temperatures under which the different freezing surfaces are being operated. The trouble that we, as manufacturers, are up against is this: Along comes a consulting engineer, who specifies the details of a plant, taking as his authority the data in Mr. Warner's paper, and he insists that the bidder must furnish a plant according to his specifications. He thinks he is safe because of the little knowledge he has obtained from such papers as Mr. Warner's, though he is particular to throw all responsibility for capacity and economy on the bidder. He pooh-poohs any idea that may be advanced that by making straighter connections, by doing away with these obstructions and twists and giving each plate a chance for its full quota of liquid and the gas to get away without interfering with the operation of the system, better results may be obtained than are shown by Mr. Warner's table, and you are between the devil and the deep sea—that is, between the consulting engineer and the purchaser.

Chairman Starr.—That is the general result.

Thomas Shipley.—You have to put an abnormal plant in or the job will go to somebody else who will, and whoever does so is sure to get into trouble.

Louis Block.—Did Mr. Warner state in his paper what the surface per ton is?

Thomas Shipley.—No, but it would not take a Philadelphia lawyer to figure it out when he gives the number and size of plates.

Louis Block.—Did he give that information?

Thomas Shipley.—Yes; he gave a whole table.

Louis Block.—I mean the lineal feet of pipe.

Thomas Shipley.—He mentioned 7-inch centres and the size of the plates, and we can easily figure the amount of coils when we get that sort of data.

Louis Block.—I have not figured it out; I think he gave it.

Thomas Shipley.—I asked him for the sizes and he gave them.

Irving Warner.—I did not give the amount of surface in the coils in our wooden tanks, for the simple reason that I knew it would not be just, and, as Mr. Shipley said, you might all note it and it would be wrong.

Louis Block.—Can you give it now?

Irving Warner.—I can, but the information would be worthless because the ice plates no longer adhere normally to the coils, and there are void spaces which are poor conductors of heat. They would fill up with water, and we freeze this water many times; so any information would be apparently more accurate than it is, and I refrained from giving it.

So far as concerns that question about the back pressure that the engines are working on, as compared with that which the tanks are working on, I said there was a difference of about half a pound pressure, and sometimes it was a little less. We had gauges on the suction line and also down at the engines. We calibrate those gauges with a mechanical calibrator probably every three months. We are very careful with the suction gauges, because we think that is the delicate part of the plant. You cannot detect the difference in reading from one place to the other. These are high-reading gauges. They have to be able to read up to 300 pounds, and 15 pounds back pressure is not a very big amount, so it is possible that a reading of half a point would be lost on it. To look at the gauges in the freezing room and at the one in the engine room, you would think they were the same. Of course we know they cannot be so, because there is a high velocity of gas through a long pipe. That may account for half a pound. So the difference between what the engines work under and what the last freezing section gives is probably a point, and I think if you go to the plants which you have seen you will find the gauges are not reading within a pound, while ours are.

I calibrated those gauges myself, and I gave one of the men explicit instructions to do so always the same way. I calibrated them again, and I found during three months that they were right. If anybody has gauges that are reading closer than ours, and gets better results, I would like to hear from him. I was asked the difference in pressure between the first and the last coil in the series, and I told you I had no information except a test made long ago by either my uncle or my grandfather. It indicated a difference of an average of 2 or 3 pounds.

It is within the province of the engineer in charge of our plant to operate any one section in such a way that the thickness of ice on the last plate is to all intents the same as on the first, and those on the intermediate will be right along with them. If the first plate is working under a couple of pounds higher back pressure, and therefore on not so low a temperature, that loss is probably made up either because there is a greater surface of contact between the liquid ammonia and the pipe in it, and is, therefore, coming along with the rest all the time, or because the last coil, instead of receiving liquid, is only getting good cool gas. Through a part of the day they may be working fast, and during the other part may be slow; and the first day may show one head pressure and the next day another, but on the last day of the week they are nearly even.

Thomas Shipley.—I want to say to Mr. Warner, if he feels so sure of his back pressure on account of his calibration—and I think Mr. Block will bear me out—different companies brought gauges to our plant straight from the manufacturer, and we placed them on a line of pipe, and no two of them registered alike, not even when we first put them there. They would change about every hour, one going up and one going down. We tried to determine the efficiency of the machine by the gauges, and subsequently we found that the only way we could do anything was with a mercury column. For suction pressures a gauge is not accurate enough for test purposes, for a pound one way or the other means a great deal on the suction side. Gauges are all right for practical purposes but not for testing.

Irving Warner.—We have only one mercury column. That column and the gauge I spoke of stayed together right along, and when they did not we took the gauge down and fixed it. We have never had to do other than our regular three months' calibration. The 200-pound gauge can be read accurately to half a point at 15 pounds when you get your face right in line with it. You cannot do it from the floor and look up. Of course, when a gauge gets old it

probably will not stick to an accurate reading at 15 pounds and also to an accurate reading at 200 pounds; but we can make an accurate calibration from 5 pounds to about 20 pounds. I try to make the gauges correct to the full range, but if they get one or two pounds out at 200 pounds I do not care, because I make them right between 5 and 20 pounds.

I do not care about what manufacturers say various gauges put on a line may do. We calibrate our plants with a mechanical calibrator. The temperature of the engine room is greater than the corresponding temperature of the ammonia, so the reading shown registers the correct pressure. For that reason I have every confidence in our gauges. They are right when they go up, and they are correct when they come down three months later.

Thomas Shipley.—I am glad to hear that Mr. Warner is satisfied with his gauges. I am not trying to shake his confidence in them. I am only calling attention to facts. It has been my privilege or misfortune to have had to hunt for these troubles with connected plates. I went through the same stunts as Mr. Warner's engineer. By rule of thumb and experience I got so that I knew what to do to meet certain emergencies on the plant I was operating, and neither Mr. Warner nor anybody else can tell what the engineer operating such a plant is really doing, nor can Mr. Warner tell what back pressures are being carried or what temperatures exist inside the freezing plates. You must know these things to know the value of the surface. You must know the internal and external temperatures to determine the value per square foot.

The point I wish to make is that, even admitting that Mr. Warner's gauges are correct, that gentleman has not given any information about his plant that is of value to us, except the amount of ice made and the quantity of coal used. His paper would have to go much deeper into the actual conditions under which the plant is operated before anyone could make use of the other figures given. It was through investigation at the Diamond Ice Company's plant—Mr. Warner's plant—that I decided that the flooded system was par excellence, and that it was the proper way of expanding ammonia.

In our President's address he told us that the foundations of successes are failures. I bought the flooded patent, which has expired, from one of the men who built the Diamond plant. The patent is over seventeen years old, and the man who got it up and described it as well as I could describe it to-day was in the employ of the men who built the Diamond Company's plant. He describes it in his

patent specifications just as well as I could to-day, after all our experiments, and still in Mr. Warner's plant they throttled the suction instead of doing the thing they knew they could do. There was something else that upset the system, but they threw it away and let it lie dormant.

Freezing of the ice in cells connected up in series shows what can be done with refrigerators connected in series, mentioned in Mr. Greene's paper, and that is the best way to find out what can be done. Put the coils in water and let us see what can be done with the series connection. The liquid enters the first plate and begins to do work, throwing gas into numbers two, three and four, until the liquid is carried over into number two, when it begins to work, and the gas formed in it is added to that from number one. This combined gas goes through numbers three and four. When the liquid carries through numbers one and two into number three it throws more gas into number four, and after number three gets a sufficient coating of ice number four gets some liquid and proceeds with its work; but this only occurs after the freezing surface in numbers one, two and three has become insulated with ice, otherwise the liquid would not come over but be used up in the other plates. This is where the loss of effective freezing surface occurs.

If you want to see the effect of a series connection just run warm water around numbers one and two plates, and see how quickly numbers three and four will lose the frost and become black. That is what happens in your series-connected refrigerators. Crowd the work in one box and it affects the others. The way to avoid this condition is to allow the gas to escape as soon as possible after it is formed.

To avoid making wedge-shaped ice you must arrange the connections so that a full supply of liquid will be kept in the whole coil. This is where the flooded system comes in, and if the builders of the Diamond ice plant had realized the value of Dr. Krebs's invention they would have saved many dollars.

J. Ensign Fuller was working on this same thing years ago. He put pockets in his expansion coils, into which the liquid dropped and remained, to be used as demanded by the conditions surrounding the pockets. If the company Mr. Greene refers to would adopt a connection that would make pockets of the coils in all of the boxes it would find less fluctuation in the temperature of the boxes under extreme duty, for each coil would have a reserve to draw from until a fresh supply came along.

What we want to do is to get at the conditions under which a

piece of apparatus is being operated. Then we can determine the value of its several parts. After we have done this there is no trouble in duplicating the performance.

There is no such thing as one man getting more than another out of a foot of pipe or a square foot of surface or a cubic foot of displacement if each piece of apparatus is operated under similar conditions. Where the rub comes in is to determine the conditions under which the apparatus is being operated, when a certain result is being obtained.

There is no standing still in our business any more than there is in any other. We must either go ahead or backward, and if we stay in the procession we must have actual facts, and we must base our opinions and designs upon solid information.

Louis Block.—I want to make a statement with reference to the difference of pressure in the expansion lines. I have only had one trial, and that was with coils 1,500 feet long, made of 2-inch pipe and with 6-inch centres. There were two coils, one on each side of the room, and they ran within 3 feet of the bottom to the top of the room. A pressure gauge was put on about 3 feet from the inlet flange of the 2-inch pipe, and the half-inch expansion valve was perhaps 6 or 8 feet away from this point. The difference between the pressure registered at that point at the inlet of the liquid and the pressure in the engine house, close to the machine, was 10 pounds. That is the only experience I have had of that nature, and I think it determined how long a coil should be. That was the first time I built a coil 1,500 feet long.

Thomas Shipley.—You see you do get a difference in temperature.

V. R. H. Greene.—Not long ago I had a chance to conduct some experiments on a straight line—at least, it was practically a straight line, as it had only four right-angle turns. One hundred and twenty-five tons refrigerating capacity was the size of the machine, and that was its full capacity. From one end of the line to the other showed that everything was working properly, as near as we could tell. We have run as much as 3,000 feet of suction pipe fitted with one expansion valve, and assuming that the back pressure runs from 10 to 15 pounds, and the insulation on all those boxes is identical, you must give us credit for being good guessers at least.

Thomas Shipley.—I will admit that; you are good guessers.

V. R. H. Greene.—We must be pretty good.

Thomas Shipley.—Yes, but only guessers.

Gardner T. Voorhees.—I desire to express my satisfaction with

Mr. Shipley's paper. I think anyone interested in mechanical refrigeration will find it of the greatest value. I believe Mr. Shipley has been working for years in a way we all must work to get the best results—that is, by throwing away the old so-called rules of thumb and getting down to the laws of nature. When Mr. Shipley finds a piece of pipe transmits so many thermal units at such a difference in temperature, you will get that result the next time if you duplicate those conditions. If other manufacturers would only make tests at their plants under the eyes of competent observers, instead of leaving them to be made on the plants of the purchasers, I think a lot more knowledge would be gained.

In line with what Mr. Shipley was speaking about, I want to cite a little experience within the last month or two in looking over bids on a 400-ton atmospheric condenser. I specified the amount of water to the condensers, the temperature of the air, and the relative humidity of the air. I also specified a fixed condenser pressure for a fixed quantity of ammonia condensed per hour, and asked a great many different manufacturers purposely how much pipe they would put in to give that result, and some of the answers were rather unusual.

I had answers from men in the business, supposed to know what they were doing, bidding on exactly the same conditions, specifying twice as much pipe to do the work as others did. Some said sixteen pipes high, some said twenty-four pipes high; others wrote that as I had designed the condenser I ought to know how many pipes I should have, without asking them. Some put it at thirty-two pipes high.

Any one of these men, with the data that Mr. Shipley has given us, can get down to hard facts and say he will put in so many feet of pipe if the conditions are so and so. That is reducing it to the laws of nature and not going on a rule of thumb. Every condition has a different requirement.

Edwin Burhorn.—Tables No. III and No. IV in Mr. Shipley's paper give results of tests on condensers in which the condensing surface is clean and entirely free from sediment, and is, therefore, in its highest state of efficiency. How long a condenser can maintain this efficiency will, of course, depend on the nature of the water used. It is fair to assume, however, that every system of water supply contains more or less sediment or material that will deposit on the condensing surface and impair its efficiency, and therefore it is only a question of time when any condenser with natural water supply will seriously lose efficiency.

A cooling tower might be worthy of consideration by the purchaser or his engineer, with a view of maintaining the original high efficiency of the condenser. By using a cooling tower and circulating the same water over and over again it will require the addition of about 5 to 10 per cent. of fresh water; therefore the scale-carrying capacity of the circulating water, by using a cooling tower, will be reduced 90 to 95 per cent., or, in other words, a condenser with a cooling tower can be run from ten to twenty times as long as one without a cooling tower before its efficiency will be reduced to such a point that cleaning is necessary. As a further aid in maintaining high efficiency, it is suggested that a water filter should be installed to purify the condensing water. As this filter should be of capacity equal to only 5 to 10 per cent. of the total amount of water to be circulated, it can be readily seen that this is a comparatively small item, and if it does remove all of the impurities in the circulating water, then, theoretically, the condenser will always maintain its highest efficiency.

Taking Mr. Shipley's table No. IV, I have worked out the cost of the water for twenty-four hours on a basis of $1 per 1,000 cubic feet and the cost of power for driving the compressor for twenty-four hours; also the cost of power for circulating the water through the condenser for twenty-four hours, on the basis of $3 per ton of 2,000 pounds, and 4 pounds of coal per horse power per hour, and have then added these costs, which give the varying costs of coal and water under the six different conditions given in Mr. Shipley's paper. These results show that, with water and coal at the prices assumed, it is cheaper to run this particular condenser at the minimum rate of flow, namely, 100 feet per minute.

I have also figured a second table, wherein it is assumed that a cooling tower is used and the loss of water is 10 per cent., or, in other words, the actual cost of the water is 10 cents per 1,000 cubic feet. I have also added the cost of pumping the water to the cooling tower, basing same on pumping against an 80-foot head. The results are given in the following tables, and under these conditions the most economical rate of flow through the condenser would be 250 feet per minute, which would give a condenser pressure of 155 pounds per square inch.

These tables are based on Mr. Shipley's figures, using water at 70° Fahr. Different temperatures and prices of water and coal would, of course, give different results. I believe a careful study of the possibilities and a thorough realization of the uncertainties should convince an intelligent purchaser of the absolute necessity of

securing the services of a competent engineer to consider all these matters before deciding on the final placing of his order.

TEN TONS OF REFRIGERATION IN TWENTY-FOUR HOURS—WATER, 70° FAHR., FROM CITY MAINS.

Condensing Water Supply.			Horse Power Per Ton of Refrigeration. Engine Driving Compressor.	Cost of Coal at $3 Per 2000 Pounds. 24 Hour Run.	Horse Power Per Ton Refrigeration Circulating Water Through Condenser.	Cost of Coal at $3 Per 2000 Pounds. 24 Hour Run.	Condenser Pressure. Pounds Per Square Inch.	Total Cost A + B + C 24 Hours.
Velocity Through 1¼-Inch Pipe. Feet Per Minute.	Gallons Per Minute for 10 Tons Refrigeration.	Cost, $1 Per Cubic Foot 24 Hours. A		B		C		
100	7.77	$1.49	$2.04	$2.94	.001	$0.001	225	$4.431
150	11.65	2.24	1.71	2.46	.004	.006	185	4.706
200	15.54	2.99	1.54	2.22	.009	.013	165	5.223
250	19.42	3.74	1.46	2.10	.018	.026	155	5.866
300	23.31	4.48	1.40	2.02	.030	.043	148	6.543
400	31.08	5.97	1.33	1.92	.071	.102	140	7.992

WATER FROM COOLING TOWER—NO FANS.

					Cost of Pumping Water to Cooling Tower Against 80-Foot Head Pressure.			Total Cost A + B + C + D 24 Hours.
		A		B	D	C		
100		$0.149		$2.94	$0.023	$0.001	225	$3.113
150		.224		2.46	.034	.006	185	2.724
200		.299		2.22	.045	.013	165	2.577
250		.374		2.10	.056	.026	155	2.556
300		.448		2.02	.068	.043	148	2.579
400		.597		1.92	.09	.102	140	2.709

Theodore Kolischer.—Mr. President, in listening attentively to the able paper read by Mr. Shipley it impressed me that one of its principal features is the advocacy to the purchaser and prospective client of the employment of a competent and able consulting engineer to aid him in the selection of the plant and to guide him through the mass of details which the purchaser is not supposed to know, and to enable him to distinguish between the bids. It is excellent advice, but from practice and experience I know—I may be wrong—that it is the practice of various concerns—not directly, perhaps, but indirectly, through their agents, canvassers, solicitors and representa-

tives—to discourage the purchaser from such employment, by discrediting the consulting engineer. I had a very good illustration of this not long ago. I met a prominent manufacturer in Philadelphia who was in the market for a 75- or 100-ton plant. On the train from Philadelphia to New York he sat next to me, and tried to obtain gratuitous advice, asking me what, in my opinion, was the best system, whether absorption or compression, and what was the best machine. I told him it was impossible to answer such questions, inasmuch as a plant of the size mentioned was not a bicycle, or a typewriter, or a sewing machine; but I did advise him to employ a consulting engineer. "Oh, well," he said, "they are all thieves." I said, "I thank you very much for such a compliment. How do you know they are thieves?" He replied, "I have been told as much by several representatives of the builders." I said, "I am very sorry for myself." Then he insisted I should take the job. I said, "No, I thank you very much; I will not." He asked me why I would not. I said, "Because I would not like to be pointed out a week or two later as a thief—as one who stole money from you." He said, "I did not mean you." I said, "I am in the same category; I thank you very much." It seems to me there should be more harmony between the manufacturer and the consulting engineer.

As a rule, the representative of the manufacturer dissuades a client from employing a consulting engineer, because he desires to remain in direct intercourse during negotiations, thinking that he will have a better opportunity to obtain the order, whereas, as Mr. Shipley said, if a purchaser were guided and aided by an able consulting engineer it would probably be much better for all concerned. I advocate, therefore, a better harmony and better understanding between the bidders or manufacturers and the consulting engineers.

W. E. Parsons.—According to my experience, the consulting engineers have had to depend largely on the manufacturers of this kind of machinery for the data which they use. They do not have many opportunities of making tests for their clients; there are not many purchasers who are willing to go to the expense of having tests of machinery made, and if they have them made they do not care about having the results published. They do not care to have consulting engineers get in their plants information that might be used for the benefit of a competitor in the design of another plant. Many consulting engineers secure their initial education from the manufacturers, and the manufacturers who are making this class of machinery are supposed to know considerable about it.

There are very few consulting engineers who build this kind of

machinery. When we come to the matter of efficiency all of the builders claim different efficiencies for their machinery or apparatus. One has a compressor which he claims is more efficient than another make. How are we going to determine which is the best when we have a lot of different specifications that are turned over to us for comparison? We are asked which is the best plant. How are we going to get the most and the best with our money? How is the consulting engineer going to decide? How many tests of our own have we to show the real efficiency of these compressors? I do not know of any way but to go to the manufacturers and ask them what they think. Ask Mr. Shipley, for instance, what is the efficiency of his compressor. He knows more about it than anybody else, and he will not mind telling you; but this does not generally agree with what somebody else says about his machine, and Mr. Shipley does not agree with what some other man says about his compressor. As we go from one manufacturer to the other we hear various stories about the efficiencies of all of the different makes of compressors. We then have to do some guessing, but the consulting engineer with the proper experience and good judgment will guess very near the truth.

As to the condenser question, a short while ago I sent out some specifications and specified the number of feet of pipe in the condenser. The president of a large manufacturing concern appeared at the office of my client and tried to convince him that his make of condenser was so much more efficient than anybody else's that he didn't have to furnish the same amount of pipe. He claimed it was useless and that he could put in a lower price if he was permitted to furnish less piping. I asked him what good it would do my client if he got all of the benefit of the efficiency by putting in less surface. He wanted to get the same results by putting in less piping. Therefore he would charge less for it and stand a better chance of getting the contract. I told him I thought that if there was any difference in efficiency he should give my client the benefit. He continued to argue that so much pipe was not necessary. I told him that if he wanted to make a point of the efficiency of his condenser he should state what condensing pressure he would guarantee with a given amount of water at a given temperature, also mentioning the other conditions. He said he would guarantee 140 pounds pressure. "Well," I said, "I will make a note of that and you can put in as much or as little piping as you want." The plant was put up that way, but the condenser pan was made large enough for more sections to go in it if they were needed. The plant has not been started

yet, but it is evident that he was a little uncertain about the efficiency for he left room to put in more condensers if needed to get the back pressure. There was a case where I asked for a given amount of pipe surface, but the bidder wanted to put in less. He got the contract and he put in less, but he will have to put in more if he does not get the 140 pounds pressure. I wanted to make a practical test of the efficiency of his condenser.

It is really hard sometimes to know just how to get the best results for a client, and I believe, as Mr. Kolischer has said, that through the combined knowledge of the manufacturer and the consulting engineer we are likely to get better results than if we try to go too much alone.

Thomas Shipley.—Did Mr. Parsons specify the number of tons capacity as well as the surface of his condenser?

W. E. Parsons.—Yes.

Thomas Shipley.—There is where Mr. Parsons tied up the manufacturer. He specified the size and the capacity of the condenser. If Mr. Parsons knew the size of the condenser he wanted why did he ask for a tonnage guarantee? He should have called for bids on the size of condenser his judgment as a consulting engineer told him was needed, he guaranteeing the tonnage himself. He gets his fee for that. It is just such cases that cause trouble between the manufacturers and the consulting engineers. An engineer who will not take any responsibility cannot blame the manufacturer if he asks the purchaser where his consulting engineer comes in, and he is also likely to say, "If I must take all the risk, why not give me all the money?"

I have tried to impress upon you several times that the time has come when the name of the manufacturer does not signify a type of machine. What is the York machine? The company builds several different types of machines, such as vertical single-acting, horizontal single-acting, vertical double-acting and horizontal double-acting—compressors having spherical heads and those which have square heads. It builds absorption machines, some using high pressure steam and others low pressure steam; in fact, a variety of machines to suit the requirements and desires of purchasers.

What is the De La Vergne machine? The company of that name builds single-acting and double-acting machines, vertical and horizontal, oil and dry gas machines, and other companies build more than one type of machine. So the term York or De La Vergne, etc., cannot be said to call for any one type of machine. There is no reason why the Vogt Company or the Carbondale Company can-

not build compression machines, or why absorption machines cannot be built in York, Waynesboro, New York or any other place.

Mr. Parsons says the consulting engineer does not have the time or opportunity to make all the tests he requires for his information. That is the fact with everyone. We have to rely upon the experiments made by different men for different objects, and make our deductions from the data obtainable. This Society is for that purpose. We come here and read papers and make data public, and stand the fire and criticism of those present, and then have men who are not able to controvert the information given say, "Well, that is only your say-so." If I come before you and give a lot of data which is the result of a great number of tests, and you do not realize its value, you are the losers, not me.

Two years ago I gave you data on the difference in running a compressor under wet compression conditions and under dry compression conditions, and I soon found that some of our "alleged wise men" were saying that what I said was a bluff; the results I gave might be all right for a machine built in York, but such was not the case with machines built elsewhere. When that came to my knowledge I said: "They will awake some day and find out whether that data is correct or not, and in the meanwhile they are the losers." Maybe some of those wiseacres will awake now when they find that Professor Linde has abandoned wet compression and puts on gloves when he feels the discharge pipes.

Something that was of much interest to me happened this summer. A large plant put in by one of the companies which advocate wet compression had failed for several years to give capacity. This summer it ran the plant dry compression and got the capacity and a settlement. The increase in capacity gained by running dry compression was over 25 per cent. The hard thing to understand is the fact that the representatives of the builder of that plant advocate the wet compression system in spite of their experience on the plant to which I have referred.

As to the data obtained from the tests made at York, I will say that the tests were open to all, and quite a number of you were there. We may have made errors, but we took extraordinary precaution to avoid them; we made over one thousand tests, and we believe our deductions are correct. We have not only given these data to you, but we have allowed others to do the same thing, and all of this has been done free of charge. All we ask is that you receive the result of our work in the spirit in which it is given to you, and that others who have made tests do the same as we are doing—make the results

public. In this way our business will be greatly benefited, and as we intend to stay in the business we will have our share of the benefits as well as you. What we want to do is to get our business down to a scientific basis. Then we can reduce our manufacturing costs to a minimum.

Gardner T. Voorhees.—I want to speak about that obscure proposition again. If I understood Mr. Shipley correctly he spoke about Mr. Parsons having tied down all ends of the proposition and then asked the manufacturer to guarantee results. That is what I think he meant. In my specifications for condensers I realize from many past specifications that if you do not tie down all the ends of a proposition and ask a manufacturer to guarantee results it is rather hard on him. But suppose you say you are going to have so many coils and so much water, and are going to condense so much ammonia, and leave it plain to the manufacturer to say, "I will put in so many pipes high and guarantee you so much pressure and so much ammonia." If because he puts in drainage drips or because of any knowledge he has he gives you for that money something that he is willing to guarantee, why not give him the benefit? I think it is the fairest way to treat the manufacturer, and I do not think it is trying to get anything unreasonable at all.

No. 46.

ADVANTAGES OF THE WET COMPRESSION SYSTEM.

By Carl W. Vollmann, Montreal, Canada.

(Member of the Society.)

Every student of refrigeration will have noticed that of the two compression systems in use, namely, the wet and the dry, the wet compression system is principally used in Europe and Eastern countries, whereas the dry system has the most advocates and is principally used in America.

I will explain, as briefly as possible, the reasons why the European refrigerating engineers prefer the wet compression system and the advantages gained by it over the dry system.

When refrigeration by compression had developed from the experimental to the practical commercial state the inventors had to decide whether it would be more advantageous to let the ammonia evaporate until all the cold had been extracted—in other words, deliver dry ammonia vapor to the compressor, thereby causing overheating of the compressor during the compression, or let the ammonia evaporate only to such a point that small particles of wet ammonia would be carried back to the compressor, which particles during the compression would absorb part of the heat developed and thereby keep the compressor at a normal temperature. Experiments were made at the time, and it was decided that the wet compression system was preferable, for the following reasons:

First—By letting the ammonia vapor return to the compressor in a partially wet state it was possible to work with a higher back pressure, thereby having the ammonia gas in the refrigerator pipes of a higher density than if the vapor was perfectly dry, consequently getting a higher efficiency. Furthermore, it was possible to keep the refrigerator pipes partially filled with liquid ammonia, in consequence of which the rapid interchange between the ammonia and the surrounding liquid is enhanced, so much so that the surface of the refrigerator pipes could be materially reduced. This saving is such that, for instance, in ice tanks the refrigerator surface in Europe is about half that supplied in the United States. Of late years the advantage of having the refrigerator pipes filled with liquid ammonia

is so well recognized in the United States that the so-called "flooded system" has been introduced to great advantage.

Second—By keeping the compressor parts at normal—that is, a cool temperature—it was found that the compressor would draw in a greater amount of vapors than where the parts are highly overheated. With a dry compressor, although the cylinder is water jacketed, the internal parts are kept at a very high temperature, and when the dry ammonia vapors are drawn into the compressor they immediately become heated, and by expanding prevent the compressor from drawing in its full amount of vapors, which it would do if this expansion had not taken place. Although this may mean only a trifle on each stroke, still it totals up to a great amount during a day's running, and thereby prevents the compressor from doing its full duty according to its measurements.

Third—By keeping the compressor and all parts connected therewith at a cool temperature, the compressor oil, which is taken into the compressor through the stuffing box, cannot evaporate, but is kept in its liquid state, and as such delivered to the oil collector, where it can easily be taken out of the system. With a dry compressor it is different, as the internal parts of such a compressor are overheated, and as soon as the compressor oil enters the cylinder part of it gasifies, and, as gas, passes with the ammonia vapors through the oil collector, and is delivered into the condenser. From here it is discharged into the refrigerator, where it gets liquefied, and covers the interior of the pipes with a solid coat of hardened oil, thereby interfering with and preventing the cold ammonia vapors from giving the cold to the surrounding fluid.

Fourth—With the wet compression system the engineer in charge knows if sufficient ammonia is circulated through the system or not by simply placing his hand on the delivery pipe. If this keeps fairly warm he knows that a sufficient amount of ammonia is passed through the system, but if the pipe should get overheated he knows that sufficient ammonia is not passed through the system, and that he has to give a greater supply so as to get the full work out of his compressor. It also enables him to decide if the compressor is fully charged or not. This is of great advantage to the engineer in charge, as well as to the manager, and is greatly appreciated by them.

As stated, the above mentioned principal advantages decided the original inventors in favor of the wet compression system, and show why the advocates of wet compression prefer to adhere to this system, although they readily admit that theoretically it would be right to let the ammonia expand to such a state that all the cold it can produce is

given off. This theoretical advantage does not, however, counterbalance the practical advantages gained by the use of the wet compression system. No doubt some of the engineers in attendance on refrigerating plants go too far by keeping the compression side too cold. This, however, is not the fault of the system, as the engineers get their instructions to regulate the supply of ammonia in such a way that the compression side is kept warm but not cold, and if this is attended to the results are all that can be desired.

DISCUSSION.

Thomas Shipley.—I regret that Mr. Vollmann is not here, as I am reluctant to criticize his paper in his absence. It is evident that Mr. Vollmann has not seen Professor Linde recently, or he would have learned from him, as Mr. Block did, that wet compression is not so much in favor, even in Europe, as it was, and as to the United States, anyone who has kept in touch with the companies which have been advocating wet compression would have found out that recently, whenever they get stuck on a guarantee, they operate their machines dry compression. Mr. Vollmann speaks about the heat of compression expanding the gas and keeping the suction gas from entering the compressor. How about the liquid ammonia that is expanded in taking up the heat of compression? What becomes of that? Does not the gas formed in this manner work the same harm in keeping out the suction gas? I am sorry that Mr. Vollmann did not see fit to give some figures and data to back up his statements. Mr. Vollmann occupies too high a position in our profession for anyone to imagine that he does not possess data on this subject; hence when he sees fit to bring such a paper as this before us, without giving us any authorities or statements as to what he bases his claims upon, it certainly shows he does not agree with some of us that it is policy to get away with the old catalogue style of things, and to come out open and above board and discuss matters pertaining to our business on a scientific basis. From what he said at our last year's meeting and from my personal acquaintance with him, I had hoped that he was willing to give his share of the general knowledge of our business, and for this reason I am much disappointed in the character of his paper.

R. L. Shipman.—What we need in papers to the Society are facts, so that we can draw our own conclusions. Conclusions without facts are usually of little value to us. What Mr. Block has said concerning Professor Linde and his wet compression system is news to me and I know it is news to practically everyone else in the

profession in this country. It seems that it would only have been wise and proper to have published this change of opinion as widely as were the original data and conclusions. This would have saved many followers of the old wet compression principles from considerable embarrassment. I have been in a large number of plants during the past year and I have found a considerable number of compressors being run wet compression, so wet that the discharge lines never went above the temperature corresponding to the discharge temperature. One engineer said: "You do not know how to make tests in this country." Another said: "Well, this machine has given good service for many years running this way and I do not care to change." The machine was a large one. I figured in this case that the machine would make 15 to 20 per cent. more ice if it were run dry, but I had no authority to order it. I was in a 250-ton ice plant that had only recently changed from wet to dry compression and the plant's output was increased some 30 tons per day. The engineer stated that he had been troubled much less with the stuffing boxes since the change was made. Now to get set right, if possible, upon this subject I wish to present considerable data.

Some of the very important results that have been produced by the test plant of the York Manufacturing Company, at York, Pa., are the comparative performance of an ammonia compressor when working under a given set of conditions with dry and with wet compression. This is a question that has not yet been very definitely settled, judging from the fact that there are many engineers, and a few builders, who still hold to the wet compression theory; indeed such was the belief of the writer previous to his experience with this test plant.

In dry compression the vapor enters the compressor dry or slightly superheated and no liquid is added during any portion of the stroke of the compressor piston. In wet compression enough liquid is taken into the cylinder to keep the vapor from being superheated during any period of the stroke of the compressor piston. There are two methods in general practice for obtaining this latter condition. One method, the one most easy of application and the most satisfactory to the operating engineer, is to supply a special expansion valve at the compressor, where the amount of liquid required to keep down the superheat is easy of control. The other method, the one most conducive to the efficiency of the cooler, is to allow enough liquid to pass through the expansion valve at the cooler so that some of the liquid is always flooding over into the compressor

The serious objection to this method is that the minimum amount of liquid thus flooding over must always be sufficient to prevent superheating and, as it is practically impossible to control the quantity of liquid through quite a wide range, there is for a greater part of the time a surplus of liquid passing through the compressor, more or less of it being pocketed in the clearance space to evaporate during the return stroke of the piston. This is very detrimental to the efficiency of the compressor. There are other methods of supplying liquid to the compressor, some of which have been patented.

Theory indicates that a considerably larger volume of vapor should be taken from the cooler per stroke of the compressor with wet compression than with dry compression and that the power necessary to compress the charge should not be very different in the two cases. For example, when working with ammonia of a zero temperature in the cooling coils and a corresponding pressure of 15.67 pounds, gauge, this margin should be some 15 to 20 per cent., if there was no interchange of heat between the ammonia and the walls of the compressor cylinder. Evidently this heat interchange is much greater than has been anticipated by many, as will be shown later. It seems highly probable that undue faith in the wet compression theory, it having been proclaimed and backed by eminent authority, has been the germ of stagnation that has prevented a more rapid development along refrigerating lines for many years, but the results gathered from the test plant of the York Manufacturing Company have broken the spell, and it is to be hoped that the end is not yet. A description of this test plant is to be found in the Transactions of 1906.

The cooler and condenser used on the tests, thirty-two in number, given in Table I, were of the Hendrick type.

TABLE I.

	Dry Compression.					Partially Wet Compression.				
R. P. M. of Compressor.	Suction Pressure at Compressor, Lbs. Abs.	Temperature Suction Gas at Cooler, F.	Temperature Discharge Gas at Compressor, F.	Lbs. of Ammonia handled per 1,000 cu. ft. of Piston Displacement.	B. T. U. Transferred from Brine per 1,000 cu. ft. of Piston Displacement.	Suction Pressure at Compressor, Lbs., Abs.	Temperature Suction Gas at Cooler, F.	Temperature Discharge Gas at Compressor, F.	Lbs. of Ammonia handled per 1,000 cu. ft. of Piston Displacement.	B. T. U. Transferred from Brine per 1,000 cu. ft. of Displacement.
1	2	3	4	5	6	7	8	9	10	11
40	30.229	12.0	202	90.02	44500	30.609	8.0	190	90.12	37000
60	30.146	12.5	222	91.22	45650	29.871	6.0	175	90.24	37700
80	29.856	10.0	238	91.88	44900	30.068	12.5	205	94.27	40600
100	29.814	11.0	242	92.84	45400	29.885	10.5	225	95.46	40300
Av.	30.014	....	...	91.48	45020	30.108	....	...	92.52	39600

The revolutions of the compressor were taken by means of a stroke counter, which was carefully checked from time to time and the suction pressure was taken by means of a mercury column. The barometer was read once an hour during the tests and corrections were made for variations in atmospheric pressure.

All apparatus was carefully calibrated, the calibrations in most cases being checked by myself. All of the original data were added and averaged by myself on a Burroughs recording adding machine, and were checked by the work done by the students who were working up the same data. Any error in the work could be easily detected by means of the records from the adding machine. In short, every reasonable precaution was taken to make this work accurate.

It may be well to mention at this time that for the tests covered in Table II the compressor was of the horizontal double-acting type, and the cooler and condenser were of the double-pipe type. Otherwise the plant was practically the same as described in the Transactions of 1906.

During the thirty-two tests previously mentioned readings were taken every fifteen minutes for a period of six hours, the plant being operated continuously day and night. When a change of conditions was made, from one to three hours was allowed for the conditions to become constant before readings were begun. Sixteen of these tests were made in four series of four runs each. During a series

of four runs no change of conditions was made except in the speed of the compressor, the four speeds run in a series being 40, 60, 80 and 109 revolutions per minute.

After the first of these series of speed changes had been run with dry compression it was repeated with wet compression. Then a change was made on the compressor and the two series were repeated. The change made on the compressor made very little difference in its efficiency, so we had two runs dry and two runs wet for each of the four speeds, and the results tabulated in Table I are the averages of the two runs for each set of conditions. Some of these results are also shown graphically in Plate 1. From this plate it may be observed that, while the liquid handled (line 2) is slightly less with dry compression, the cooling done (line 1) is about 15 per cent. more with dry than with wet compression, and, further, the cooling decreases rapidly toward the lower speeds with wet compression.

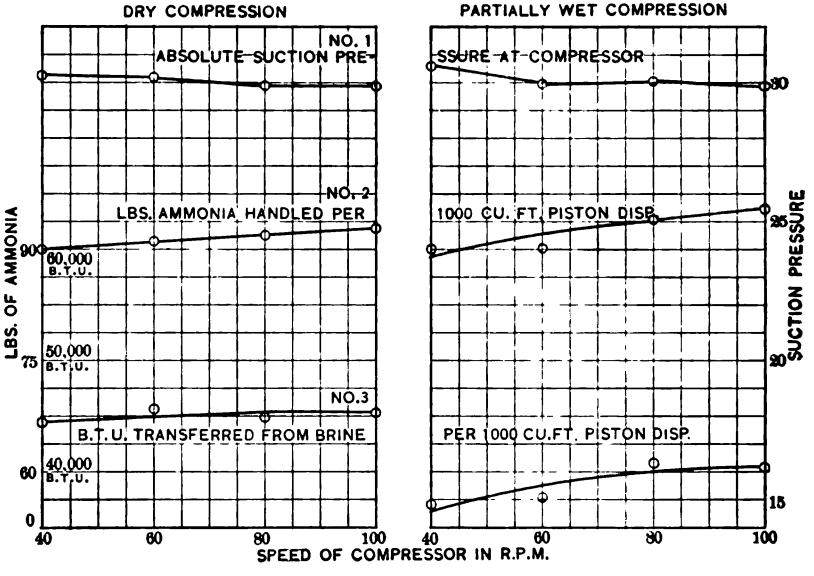

PLATE 1.

For the first wet compression test the wetness was obtained by flooding the cooler, which was of the Hendrick type, but the conditions were so irregular that the test was thrown out. Then the compressor was provided with two expansion valves, one in each suction line just outside of the stop valve, and the test was repeated with much more constant conditions. The remainder of the wet com-

pression tests in the series of Table I were made in this way, the temperature of the gas leaving the cooler being kept as nearly as possible the same as in the dry compression tests. The temperature of the discharge gas in the wet compression tests was run high to satisfy the man at the expansion valve, who protested that the more liquid expanded at the compressor the less could he expand at the cooler, and that the temperature range of the brine decreased with the increasing wetness. Now, if there is any merit at all in the wet compression process the reverse should have been the result.

During the summer of 1904 the writer participated in two other series of runs comparing wet with dry compression. The change made in the first of these two series was the temperature of the discharge gas, it being changed by increments of about 50° from the temperature corresponding to the discharge pressure, to the highest temperature that could be had with the discharge pressure of 185 pounds, gauge. The discharge temperatures ran about 95°, 150°, 200°, 250° and 285°, the last one being the average for the run without jacket water and with slightly superheated gas entering the compressor. This maximum discharge temperature was surprisingly low for the pressures run, which were about 15 pounds suction and 185 pounds condenser pressure. Many tests were run later on this compressor at the above pressures without jacket water. The second of these two series was run under practically the same compressor conditions, except in the reverse order. The results of these two series showed that the higher the temperature of the discharge gas the more cooling was done per minute of piston displacement and per unit of power expended.

If any change can be made on the compressor that will cause it to take more gas from the cooler per stroke at a given back pressure, the back pressure would begin to decrease when that change was made, and more heat would have to be added to the brine to keep this pressure constant; and for a constant rate of circulating the brine the range in its temperature would increase. These are the results we should expect from cooling the compressor by liquid injection, but the reverse has always been the case in this test plant, and it is safe to say, in any practical case, that injecting liquid into the compressor will cause a higher back pressure, and consequently a higher temperature in the cooler, thus decreasing its efficiency by decreasing the difference in temperature between the refrigerating agent and the substance to be refrigerated. There may be some cases of badly designed plants in which the plant efficiency would be greater with wet compression than with dry compression.

During the summer of 1905 the York Manufacturing Company built a horizontal double-acting cylinder, 12½ by 18 inches, having the same piston displacement as the two vertical single-acting cylinders, except for the piston rod, and hitched it tandem to the same engine cylinder and repeated many of the tests that had been made on the vertical cylinders. Among the tests made were many on wet compression, with the same results as had been previously found with the vertical compressor, only worse for wet compression. But the management of the company, not wishing to leave a stone unturned in these important investigations, secured the services of two practical engineers who had had many years' experience in erecting and operating wet compression plants, one to be the operating engineer in the test plant during the day and the other to take the same position at night. The services of an expert, an advocate of wet compression, were secured to dictate the conditions of operation and see that they were carried out. The remainder of the day and night crews were made up of quite competent help. Many tests were then made with wet and dry compression, but no point was made in favor of wet compression. After the expert had apparently taxed his wits to the limit for some winning condition for wet compression, he finally admitted that he had observed this apparent discrepancy between theory and practice as much as fifteen years earlier. He said that at about that date he had charge of an acceptance test on a wet compression machine, and that his engineer came and reported that it was impossible to make the rating without running the discharge gas hot, and it was so run. But this expert had too much faith in the "sayings" from the fatherland to give up the theory. The two expert operating engineers likewise stated to the writer that many times they had been compelled to run the discharge gas hot to make the rating on the plants in their charge.

Table II contains results from tests on the horizontal compressor and comprises some very instructive data.

TABLE II.

Compression.	No.	Suction Pressure, Lbs., Gauge. 1	Temperature Corresponding to Suction Pressure, F. 2	Range in Temperature of Brine. 3	Ice Melting Effect, Tons in 24 Hours. 4	Discharge Temperature Observed at Compressor, F. 5	Condensing Water, Gallons per Minute. 6	Range in Temperature of Condensing Water, F. 7	Condensing Water in Gal. per Min. per Ton. 8	Range of Temperature, F., of Cond. Water Multiplied by Gal. per Min. per Ton. 9
Dry	1	5.70	—7.83	4.50	16.88	294	17.9	23.42	1.06	24.8
"	2	5.08	—5.46	4.73	17.69	307	17.2	23.80	.97	23.2
"	3	5.60	—1.15	5.02	19.50	306	17.9	24.74	.92	22.7
"	4	5.34	1.85	5.72	22.63	294	19.0	25.85	.84	21.7
"	5	5.31	1.39	5.34	20.19	293	18.7	26.76	.93	24.8
"	6	5.55	—2.05	5.21	19.59	320	16.8	26.90	.86	24.0
"	7	5.11	....	5.41	20.87	331	19.6	24.88	.94	23.4
"	8	5.05	....	4.44	17.38	332	17.4	24.64	1.00	24.6
Wet	9	5.80	—16.16	2.22	8.30	215	14.6	21.87	1.76	38.5
"	10	5.85	—15.81	1.35	5.06	95	13.9	21.68	2.24	59.5
"	11	6.25	—15.54	1.85	7.20	100	14.6	23.44	2.06	47.5
Dry	12	15.95	1.67	7.20	26.61	242	27.6	25.42	1.04	27.4
"	13	15.34	8.23	8.67	34.21	263	32.2	25.71	.94	24.2
"	14	15.98	15.72	8.40	32.36	262	31.3	27.00	.97	26.1
"	15	15.16	12.94	7.48	26.19	284	25.3	27.24	.97	26.3
"	16	15.99	10.36	7.63	29.36	286	29.7	26.00	1.01	26.6
"	17	15.16	7.13	8.12	31.33	267	34.6	24.28	1.10	26.8
Wet	18	15.68	.39	4.41	17.05	126	26.7	20.69	1.57	32.4
"	19	15.71	.08	3.25	12.80	95	21.5	22.63	1.67	38.0
"	20	15.76	.37	3.61	13.74	100	19.2	24.71	1.40	84.5
"	21	15.73	.11	4.64	17.46	95	24.6	24.04	1.41	33.8
"	22	15.87	1.10	3.39	13.28	105	21.5	23.27	1.62	37.6
Dry	23	24.78	21.19	9.45	37.42	264	42.7	23.16	1.16	26.4
"	24	24.65	25.28	9.48	38.14	262	41.3	24.11	1.08	26.1
"	25	24.59	18.42	10.37	38.49	250	42.4	24.02	1.10	26.5
"	26	24.84	20.64	11.38	41.85	246	43.1	24.04	1.03	24.7
"	27	25.36	25.07	11.25	42.45	252	41.2	26.48	.97	25.7
Wet	28	24.84	11.60	7.75	30.50	158	41.2	21.62	1.35	29.2
"	29	24.84	10.91	7.27	28.81	111	39.9	22.19	1.38	30.7
"	30	25.01	12.18	7.32	28.81	104	42.7	22.32	1.48	33.1

NOTE:—Head pressure for all tests 185 pounds, gauge; speed of compressor constant.

While there were many other tests made on this compressor, comparing dry and wet compression, the tests quoted from here were not selected for their special qualities. It is a block of consecutive tests, all made within a period of four weeks. They show what all other comparative tests show—the great loss from running a compressor under the conditions of wet compression. These were not trifling one- and two-hour tests, as many of them were run from three to twelve hours, and none for less than five hours. The speed and performance per unit of piston displacement has been omitted from this table to avoid a discussion on the comparative efficiency of single- and double-acting compressors. In this table it will be interesting to compare the tonnage made at a given back pressure for the two conditions of dry and wet compression, as all of the tests were made at the standard head pressure of 185 pounds, gauge. It is to be especially observed that this difference increases rapidly as the suction pressure decreases. The tonnage made with dry compression at 5 pounds suction pressure is nearly three times that made with wet compression at the same suction pressure, while at 25 pounds the difference is only about half more in favor of dry compression. The difference would evidently continue to decrease with a decrease in the ratio of pressures, either by increasing the suction pressure or by decreasing the head pressure. This is quite clearly shown in Plate 2. The same conclusion is borne out by the range in temperature of the brine, as the brine was circulated at the same rate for all tests of Table II, by comparing the tonnage and the discharge temperature in lines 7, 8 and 9 of this table. In line 7 the superheating is about 120°, and the tonnage is considerably more than for either of the other tests at the same pressure. The maximum amount of superheating to be expected at 6 pounds, gauge, suction pressure and 185 pounds, gauge, head pressure should be about 250° if no liquid enters the compressor and no jacket water is used.

From Plate 2 it is to be especially observed that the curve No. 1, showing the performance of the compressor under the conditions of dry compression, is practically a straight line passing through the origin, showing that the performance under these conditions is nearly directly proportional to the suction pressure; while with wet compression the performance curve No. 2 runs much below for the low suction pressures and approaches the dry compression curve toward the high suction pressures. While these curves are somewhat indefinite, owing to the small number of points through which they are drawn, it can be pretty safely inferred that if the suction

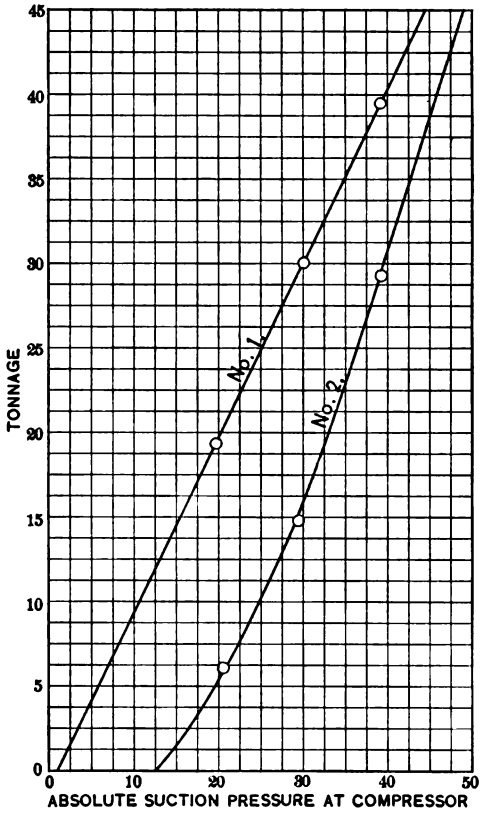

PLATE 2.

pressure had been run at about 60 pounds, absolute, there would have been practically no difference in the performance under the two conditions of dry and wet compression with the head pressure of 185 pounds, gauge. This same observation is to be made from Table III and Plate 3, which will be discussed further on.

The claim is often made by advocates of wet compression that the amount of condensing water needed with wet compression is less than with dry compression. This is not true in theory nor in practice, and we have some very instructive data on the subject in Table II. While the actual amount of condensing water used per unit of piston displacement may be less for a given set of conditions with wet compression than with dry compression, as shown in column 6 of Table II, the amount of condensing water used per unit of cooling done is much more for wet compression, as shown by column 8.

These differences increase toward the lower pressures, as is clearly shown by these two columns of data. A portion of this difference in efficiency of condensing water is due to the impossibility of getting as high a range in temperature of the water with wet compression as with dry compression. With dry compression about 10 per cent. of the range in temperature of the condensing water is produced by the superheat in the gas, while with wet compression this superheat does not exist. The comparative use of condensing water is also clearly shown by column 9 of this table. This column shows the product of gallons of condensing water per minute per ton by its range in temperature. This product, if the radiation from the system is constant, should be very nearly a constant quantity for all ranges in temperature of the condensing water. For normal conditions of operation with dry compression this constant should be about 28—i. e., for 1 gallon a minute per ton the range in temperature should be about 28, and for 2 gallons a minute per ton the range should be about 14, etc. From this column it is to be observed that the difference between the values of this constant for wet and dry compression increases toward the lower pressures, like the other differences that have been observed.

Incidentally, it may be observed that while with dry compression this product is very constant for a given suction pressure, it increases toward the higher suction pressures. This is due to the fact that during the tests of Table II a constant quantity of condensing surface was used of the double-pipe type, which has a considerable radiating surface. As the suction pressure increased, the work on the condenser increased, requiring a larger amount of water per unit of condensing surface, and the percentage of heat dissipated by radiation decreased.

Another important observation I have made in reviewing the records of many tests is that the friction load runs uniformly higher for wet compression than for dry compression for the same suction and discharge pressures. About the only reason that can be assigned for this is that during wet compression the oil in the cylinder and stuffing boxes gets very stiff from the low temperatures to which it is subjected, but no special attention was paid to the stuffing boxes during these tests, that being left entirely to the judgment of the engineer in charge of the compressor. We usually had a man of extensive experience at that post, and it is to be assumed that the same conditions are to be expected in general practice.

An advantage claimed for wet compression by the advocates of that system is that the deterioration of ammonia is much less than

with dry compression, but it is doubtful if this is to be taken seriously. No good data are at hand on that subject, but compression temperatures with dry compression are not as high as usually expected.

While it is true that the stuffing box has been a considerable source of trouble with dry compression on double-acting compressors, these troubles certainly are far more than offset by the gain in efficiency of the compressor working under the conditions of dry compression. It is probably safe to say that the majority of the troubles with stuffing boxes come from irregular temperatures, to which they are subjected. Any packing that contains a considerable quantity of rubber has a large ratio of expansion, and a change in temperature of a few degrees makes it too tight or too loose, with obvious results. These troubles can largely be eliminated by the use of a cooler of modern design or by remodeling the old one, so that the gas will be delivered to the compressor with only a few degrees of superheat and at a constant temperature without the danger of entrained liquid. During these tests on the double-acting compressor special observations showed that with suction gas at about 5°, superheat and discharge gas at about 300°, the temperature of the piston rod ran at 150° to 200°, much lower in temperature than that of the steam piston rod.

It probably will be of interest to examine in this connection the results of some early tests. For that purpose Table III has been rearranged from Table A of M. Ledoux's "Ice-Making Machines."

TABLE III.

Compression.	Authority.	No.	Suction Pressure, Absolute. 1	Corresponding Temperature, F. 2	Suction Pressure, Gauge. 3	Condensing Pressure, Gauge. 4	Condensing Pressure, Absolute. 5	Difference Between Suction and Discharge Pressures. 6	Ratio of Absolute Pressure. 7	B.T.U. Transferred from Brine per 1,000 cu. ft. of Piston Displacement 8	Revolutions per Minute of Compressor. 9	Ice Melting Capa. Tons in 24 Hours. 10
Wet	Schroter	1	22.2	—11.8	7.5	111.7	126.4	104.2	5.7	26100	44.8	9.0
"	"	2	23.7	—9.4	9.0	110.9	125.6	101.9	5.4	31100	44.7	9.9
"	York	3	30.1	0.0	15.5	185.0	199.7	170.0	6.8	39600	40–100	..
"	Schroter	4	30.3	0.5	15.6	113.3	128.0	97.7	4.3	38600	45.1	13.3
"	"	5	41.9	14.3	27.2	116.7	131.4	89.5	3.1	58000	45.1	19.5
"	"	6	41.9	14.4	27.2	184.8	199.5	157.5	4.8	49200	45.0	16.5
"	"	7	41.0	13.1	26.3	102.2	116.9	75.9	2.8	60000	45.0	20.0
"	"	8	45.1	17.8	30.4	116.7	131.4	86.3	2.9	66000	45.1	21.6
"	"	9	55.3	26.6	40.6	120.7	135.4	80.1	2.5	78500	44.9	26.2
"	"	10	60.0	30.2	45.3	121.1	135.8	75.8	2.3	88500	45.2	29.8
"	"	11	60.3	30.7	45.6	115.3	130.0	69.7	2.2	82600	31.7	19.5
Dry	Denton	12	22.9	—10.8	8.2	152.3	167.0	144.1	7.3	33000	57.7	37.9
"	"	13	27.7	—3.2	13.0	147.3	162.0	134.3	5.8	42000	57.9	46.5
"	York	14	30.0	0.0	15.4	185.0	199.7	170.0	6.8	45000	40–100	..
"	Denton	15	42.2	14.5	27.5	161.3	176.0	133.8	4.2	63200	58.9	74.4
"	"	16	42.7	15.0	28.0	151.3	166.0	123.3	3.9	63700	58.1	73.9

In Table III these tests have been arranged according to suction pressures. Some of the columns of data of Table A have been omitted from Table III, and others have been computed by me to present more clearly the subject under discussion. The average results of the York tests of Table I have been also included in this table. The relations of some of these results can be more clearly shown by the graphical method, and are thus presented in Plate 3. From this plate it is to be observed that the points showing the performance of the dry compression machine at the different suction pressures fall practically in a straight line, passing through the origin, as was the case in Plate 2. But the points for the wet compression tests are very irregular and fall considerably below those for the dry compression tests at the same suction pressures, in spite of the fact that they were made at much lower condenser pressures. It seems exceedingly unfortunate that these early tests should have been made under conditions that are so impractical and conditions that are especially favorable to wet compression. The suction pressures, with three exceptions, were too high for any considerable amount of work except brewery work; and the head pressures, with only one exception, were entirely too low for any season of the year,

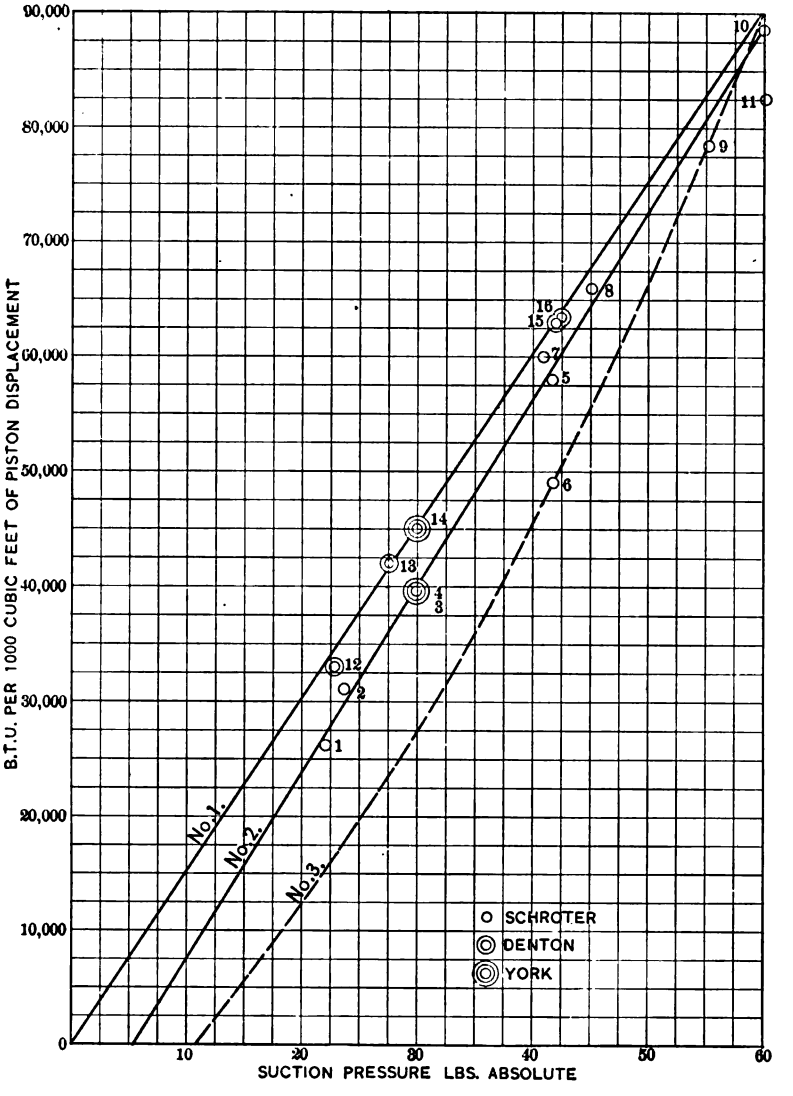

PLATE 3.

except winter, at which time only a small percentage of refrigerating is done.

High head pressures are productive of disastrous results with wet compression, as is clearly shown by Table II and Plate 2, and the same result is shown by these early tests. While it is somewhat hidden in the table, it is shown very clearly by the graphical method

in Plate 3. For example, point No. 6 in Plate 3 is the point located by test No. 6 of Table III, which was made at the head pressure of 184.8 pounds, gauge. Now, if we pass a curve through the point where line No. 1 of Plate 3 intersects the suction pressure ordinate of 60 pounds, absolute, and direct this curve through point No. 6, we get curve No. 3, which is very similar to curve No. 2 of Plate 2. It seems highly probable that if a series of tests had been made on that machine at that time with a constant head pressure of 185 pounds, gauge, and for a series of suction pressures, some such curve as No. 3 would have been produced.

A very important observation to be made from these results is that decreasing the speed of the compressor decreases the efficiency of the compressor with wet compression. For example, test No. 11, of Table III, was made at 31.7 r. p. m. of compressor, while all the others were made at about 45 r. p. m. It is to be observed that the cooling of the brine per unit of piston displacement, as shown in column 8, is about 7 per cent. less than that for test No. 10, in spite of the fact that test No. 10 was made at a slightly less suction pressure and a little higher head pressure. It is to be remembered that this same speed effect was observed from Table I and Plate 1.

It may be worth while to examine some mean effective pressure curve in this connection, and Plate 4 has been arranged for that purpose. Curve No. 1 of this plate is for a head pressure of 114 pounds, gauge, and its corresponding temperature of 70°, which is the average head pressure of the wet compression tests 1, 2, 3, 5, 7, 8, 9, 10 and 11 of Table III. To examine this curve more closely it is to be observed that by increasing the suction pressure from 15 pounds, gauge, to 45 pounds, gauge, the work on the driving engine increases very little for any of the intermediate pressures, and that this work is a little less at 45 pounds than at any of the other pressures beyond the 15 pounds. From this it can be seen that there would be a very strong inducement to keep the suction pressures high so long as the compressor is the only element of the refrigerating system under consideration. But in most practical cases we are confined to much lower suction pressures by the low temperatures to be carried in the coolers. Curve No. 2 is for a head pressure of 153 pounds, gauge, and its corresponding temperature of 75°. This is the average head pressure of tests 12, 13, 15 and 16 of Table III. Curve No. 3 is for a head pressure of 168 pounds, gauge, and its corresponding temperature of 90°. This is the pressure that has been recommended by the committee of the American Society of Mechanical Engineers as the one at which to rate the ammonia compression machine.

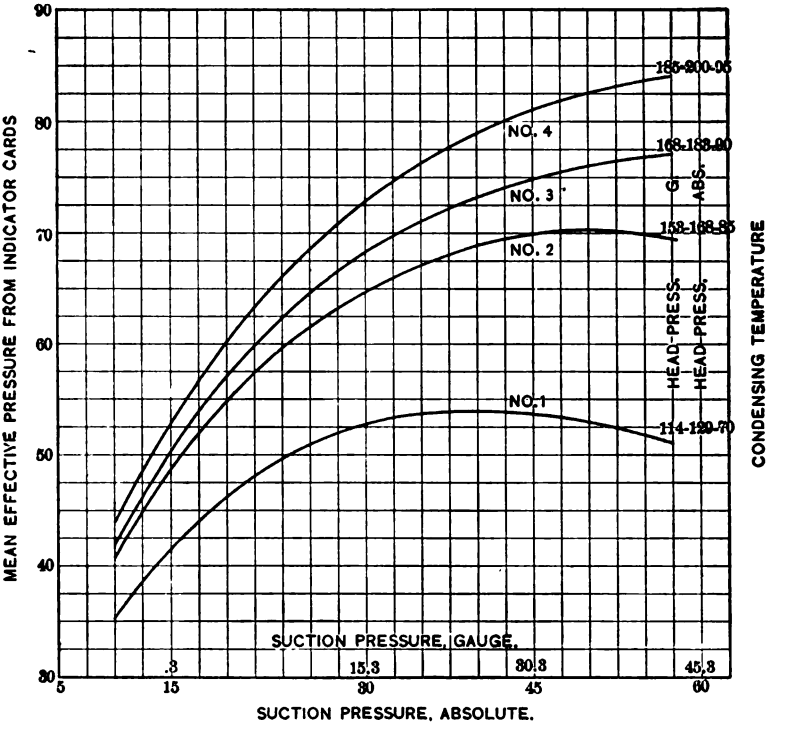

PLATE 4.

Curve No. 4 is for the head pressure of 185 pounds, gauge, and its corresponding temperature of 95.4°. This is the pressure that has been recommended by the Ice Machine Builders' Association as the one at which to rate the ammonia compression machine, and is one at which all of the York tests quoted from in this discussion were made. Such curves as those in Plate 4 will bear a great deal of study in the economic problems of refrigerating engineering.

Then, in the light of all this experimental demonstration, there must be some plausible reason for this apparent discrepancy between theory and practice, and so there is. It is as follows: It has long been conceded by eminent authority that the major part of the loss in efficiency of the ammonia compression machine is due to the heat interchange between the ammonia and the walls of the cylinder, commonly known as cylinder heating. It certainly must be conceded by the same authority that when liquid enters the cylinder this heat interchange is much greater than when only a dry gas enters the cylinder, in spite of the fact that the mean difference in temperature

between the cylinder walls and the ammonia is much greater in the latter case. We have an analogous case in the steam engine. For many years it has been a well-known fact among steam engineers that the heat interchange between the steam and the walls of the cylinder is much less with superheated steam than when wet steam is used. For example, in quite common practice saturated steam loses 25 per cent. of its heat to the walls of the cylinder during the admission period of the stroke, and this is well known as cylinder condensation. At 100 pounds gauge pressure the latent heat of vaporization of steam is 875 B. T. U., and 25 per cent. of this is about 220 B. T. U., enough heat to superheat the steam to about 450°, and, theoretically, it would take more than this amount of superheat to annul cylinder condensation, owing to the great mean difference in temperature between the steam and the cylinder walls. But in practice it has been found that a much lower degree of superheat will annul all cylinder condensation, 150° being sufficient in most cases. The reason for this is that a dry gas absorbs or imparts heat much more slowly than a saturated or wet vapor. Not until some method that will prevent the heat interchange between the vapor and the walls of the cylinder is devised can we hope to approach the goal promised by theory for wet compression. Incidentally, from this same analysis, we can also see a reason for the fact that compounding ammonia compressors do not show the gains usually expected, but there probably is plenty of reason for compounding.

The result of the foregoing data and remarks can be summed up in a few general conclusions, as follows:

1. That in general no liquid should enter the cylinder of the compressor, and that wet compression has a very narrow field of practical application, if any at all.

2. It is important to keep the ratio of head pressure to suction pressure very low with wet compression.

3. With wet compression the efficiency decreases toward the lower speeds of the compressor, due to the greater time allowed for the heat interchange in the cylinder.

4. The carbonic acid machine might work more efficiently with dry compression.

5. The foregoing disclosures emphasize the importance of testing a theory by actual experiment over the entire field to which it is to be applied.

No. 47.

*THE WORK OF THE UNITED STATES GEOLOGICAL SURVEY IN ITS RELATION TO REFRIGERATION.**

By R. B. Dole, United States Geological Survey.

(Non-Member of the Society.)

The refrigerating engineers and ice manufacturers who were at the Jamestown Exposition evinced so much interest in the water investigations of the United States Geological Survey that your Secretary has kindly invited me to outline the work that is being conducted by the Water Resources Branch in its relation to refrigeration and to the manufacture of ice.

In this period of increasing scrutiny and careful examination of production costs for all industrial processes, manufacturers are giving more attention to the quality of their water supplies, because water in some form is necessary for the operation of every establishment. Not many years ago water was water for the practical man if it would flow through a pipe in sufficient amount. But more and more he has been obliged to modify his views, previously limited only by the quantity of available water, by considering the part of his production cost that is due to the use of water unsuitable in quality for the particular manufacturing process that he has in hand. Since water is the greatest natural solvent and dissolves more or less of everything with which it comes in contact, it follows that natural waters contain a great variety of matter in solution and suspension and that their relative purity depends on the locality from which they come. Waters that have percolated through limestone are hard, those that have traversed regions of alkali are alkaline, the drainage from swampy places is colored and contains much organic matter, while that from populated districts is polluted by disease-bearing organisms that render it unpotable. It is, therefore, important to study the peculiar composition of different waters and their adaptability to various industrial processes.

It is not necessary to describe minutely the processes of refrigeration; indeed there is probably no engineer present who is not

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better informed on the subject than I. It is, however, easy for one with only a theoretical knowledge of this great industry to see that the quantity and the quality of the water supply are of material consideration in the economical operation of refrigerating machinery. In regard to quantity, a refrigerating plant requires from 1,500 to 7,500 gallons of water per day for each ton of refrigerating duty. Its claim to position among the great water-consuming industries is established by the fact that more than 20,000,000,000 gallons of water are used every year in the United States for the manufacture of ice alone, without counting the possibly greater amount required in other refrigerating plants. Twenty million gallons of water is sufficient to supply a city of 500,000 inhabitants.

Quality is equally important. The water is used for steaming purposes and, therefore, its mineral content materially affects the boiler service. Every pound of scale deposited in the boiler reduces the fuel efficiency and increases the cost of boiler repairs and cleaning, thereby shortening the life of the boiler and decreasing its time of intermittent service. The increased consumption of fuel necessitated by a scale deposit one-sixteenth of an inch thick has been variously estimated at from 10 to 17 per cent. according to the method of experimentation employed by the estimator and the physical structure of the scales he tested. A railway chemist of wide experience stated a short time ago that the use of unsoftened feed water costs on an average $710 per year per locomotive in the United States, or an annual waste sufficient to purchase 2,200 new engines. A careful estimate of the cost of using feed water containing 360 parts per million of incrustants in a 1,000 horse power boiler, as compared with the use of the same water after being softened, shows that the saving in the boiler room alone amounts to slightly over $1,600 a year, or nearly half the cost of installing a purification plant.

The temperature of the water applied to the condensers must be taken into account, together with its corrosive or incrusting effect on the condenser coils themselves. F. W. Pilsbry has demonstrated that a plant using condenser water at 80° Fahr. cannot produce so much ice as one using water at 60° Fahr. when both plants have compressors of the same size and speed; and that for the higher temperature both the condensing surface and the quantity of water that runs over it must be increased. The same author states that if, on account of the temperature of the water, the condensing pressure must be 205 pounds instead of 145 pounds, the fuel consumption is increased 40 per cent. and the water consump-

tion is doubled. The chemical composition of the water affects the condensing temperature, because every pound of sludge deposited on the coils means an equivalent decrease in the cooling effect of the applied water. The solvent action of corrosive matter in the water results in the destruction of ammonia coils and condenser tubes.

The popular requirements for the quality of domestic ice are as exacting as those for the quality of water supply. The ice consumer demands a product that is colorless, transparent and free from dangerous pollution. This necessitates the use of perfectly safe water or the adoption of special means for purifying the unsafe supply. In the can system, the removal of mineral impurities involves distillation, and, if the water supply is unpotable, special precautions are necessary to prevent the pollution of the frozen product. Recent improvements in the plate system have resulted in the production of ice from badly polluted water that is æsthetically unobjectionable, but whether such ice is pure from a bacteriological standpoint is still a subject of research.

There are, in fact, few characteristics of water supply, physical, chemical or biological, that do not become factors in its use for refrigerating and ice-making establishments. By consideration of the features that have been briefly touched upon, it can easily be seen that the quantity and the quality of water are very important factors in the cost production per ton of refrigerating duty. It was felt for several years by those interested in the work of the Geological Survey that water, the most valuable mineral, should be given special attention on account of its intimate relation to manufacturing interests and to the general development of the country. Accordingly there was established a Hydrographic Branch, or Water Resources Branch as it is now called. Its object is the purely economic one of determining the value of the water resources of the country. Its work has been to measure the flow of streams and especially to determine the value of undeveloped water powers, to investigate underground water basins and their availability for local industries, and to determine the quality of both surface and ground waters in relation to domestic supply and industrial consumption. The results of these investigations are published reports, which constitute the manufactured products of the branch. They are usually printed as water-supply papers, small-sized volumes of 100 to 200 pages each and written in as popular style as the subject matter will permit. Since 1896 over 200 of these papers have been prepared and printed, embracing all manner of subjects relating to water, such as reports on

surface water supply, underground waters, water power, quality of water, pumping water, irrigation, descriptive geology and general hydrographic investigations. River measurements have been made at 1,500 stations in the United States and Alaska. Underground water investigations have been completed or are now in progress in practically every State and Territory.

One recent investigation that has been carried on, the results of which are expected to be of interest to all members of the engineering profession, is a study of the chemical composition of surface waters in the United States. About 180 stations were established at which daily samples of water were collected for a period of one year. These daily samples were united in sets of ten and the composite then subjected to complete mineral analysis. The analytical work on this large investigation has nearly been completed. The results are now in process of compilation and the printed reports on them will probably be ready for distribution in May, 1908. These reports will contain special chapters on the use of the different waters in the industries, including refrigeration and ice manufacture. These synopses of the application of the water will assist the prospective manufacturer in locating his establishment and will enable him to make very definite allowances in his estimate of cost production for the purification of his water supply. The appended table gives some idea of the diverse composition of American rivers and lakes as determined by this investigation. Only a few of the more important determinations that were made in each sample are given. Each set of figures is the average of from ten to forty analyses.

COMPOSITION OF WATER OF AMERICAN RIVERS AND LAKES.

[Parts per Million.]

SOURCE.	STATE.	Suspended Matter.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Carbonates (CO_3)	Bicarbonates (HCO_3)	Sulphates (SO_4)	Chlorine (Cl)	Total Dissolved Solids.
Raritan River	New Jersey	28.0	17.0	0.15	11.0	4.5	7.6	1.2	48.0	11.0	4.1	85.0
Potomac River	Maryland	25.0	8.4	0.13	22.0	4.3	8.3	0.0	32.0	54.0	5.1	121.0
Susquehanna River	Pennsylvania	24.0	9.8	0.09	18.0	4.6	8.6	0.0	52.0	28.0	5.1	106.0
Miami River	Ohio	71.0	18.0	0.15	63.0	27.0	8.4	5.6	253.0	42.0	3.6	394.0
Monongahela River	Pennsylvania	62.0	7.3	0.62	12.0	2.9	6.8	0.0	15.0	38.0	2.8	85.0
Kentucky River	Kentucky	163.0	16.0	0.59	24.0	4.3	6.1	0.0	85.0	7.8	1.5	116.0
Grand River	Michigan	40.0	16.0	0.06	60.0	20.0	9.4	4.9	230.0	3.4	6.4	273.0
Hudson River	New York	14.0	12.0	0.13	20.0	3.8	8.0	0.0	72.0	17.0	3.4	112.0
Allegheny River	Pennsylvania	40.0	8.0	0.13	14.0	3.1	10.0	0.0	38.0	17.0	12.0	87.0
Delaware River	New Jersey	18.0	10.0	0.08	11.0	3.1	4.8	0.0	39.0	11.0	2.2	65.0
Oswegatchie River	New York	7.6	11.0	0.16	13.0	3.9	5.7	0.0	52.0	7.8	0.2	83.0
Roanoke River	Virginia	110.0	20.0	1.0	9.6	3.7	5.7	0.0	53.0	3.9	2.0	80.0
James River	Virginia	42.0	20.0	0.54	14.0	3.1	4.0	0.0	58.0	7.9	1.5	86.0
Maumee River	Ohio	105.0	18.0	0.17	60.0	16.0	28.0	1.9	186.0	54.0	42.0	338.0
Youghiogheny River	Pennsylvania	255.0	7.5	0.18	21.0	5.8	6.0	0.0	0.0	110.0	3.2	176.0[a]
Muskingum River	Ohio	64.0	16.0	0.15	46.0	9.7	25.0	1.0	122.0	44.0	44.0	261.0
Savannah River	Georgia	85.0	24.0	0.8	5.9	0.5	4.8	0.0	22.0	0.7	2.5	58.0
Tombigbee River	Alabama	118.0	25.0	0.47	14.0	2.3	2.5	0.0	48.0	0.9	3.2	89.0
Tennessee River	Kentucky	153.0	19.0	0.58	18.0	5.1	4.7	0.0	68.0	6.2	2.7	102.0
Chattahoochee River	Georgia	126.0	24.0	2.4	5.1	1.0	1.9	0.0	20.0	Trace	2.6	63.0
Illinois River	Illinois	25.0	12.0	0.20	51.0	21.0	17.0	0.0	195.0	48.0	13.0	260.0
Arkansas River	Arkansas	722.0	31.0	1.20	53.0	13.0	138.0	0.0	143.0	89.0	194.0	670.0
Brazos River	Texas	1206.0	20.0	0.20	116.0	20.0	226.0	0.0	161.0	262.0	331.0	1098.0
Chippewa River	Wisconsin	5.2	12.0	0.21	13.0	4.6	8.1	0.0	47.0	14.0	1.1	90.0
Des Moines River	Iowa	604.0	22.0	0.40	56.0	21.0	17.0	0.0	140.0	68.0	4.7	313.0
Missouri River	Missouri	2112.0	39.0	0.71	62.0	17.0	46.0	0.0	202.0	141.0	12.0	434.0
Wabash River	Indiana	191.0	13.0	2.9	59.0	21.0	26.0	0.0	222.0	58.0	41.0	349.0
Kansas River	Kansas	88.0	47.0	20.0	76.0	19.0	89.0	5.0	292.0	73.0	63.0	474.0
Sacramento River	California	61.0	19.0	3.4	14.0	6.5	14.0	0.0	63.0	13.0	7.5	96.0
Androscoggin River	Maine	----	8.0	3.4[b]	7.1	1.0	3.5	---	----	11.0	2.5	41.0
Mississippi River	Louisiana	----	11.0	0.15	32.0	8.3	15.0	---	110.0	23.0	9.7	166.0
Lake Superior		----	7.4	0.06	13.0	3.05	3.2	0.0	56.0	2.0	0.9	60.0
Lake Michigan		----	10.0	0.01	26.0	7.8	4.1	3.4	109.0	6.4	2.2	116.0
Lake Huron		----	10.0	0.05	24.0	6.5	3.4	1.7	99.0	5.8	3.0	105.0
Lake Erie		----	6.8	0.08	31.0	7.3	6.4	2.4	118.0	12.0	7.1	134.0
St. Lawrence River		----	7.1	0.05	31.0	7.2	6.4	2.9	116.0	16.0	6.2	135.0

a Free sulphuric acid (H_2SO_4), 20 parts.
b Ferric oxide and alumina.

DISCUSSION.

S. P. Stevenson.—I wish to ask what the material is, unless it is given. What is the name of the river?

R. B. Dole.—The Brazos. The first column represents suspended matter. In some of the Southern rivers it is hard to tell whether it is mud or water. One of our hydrographers told us in working on the Rio Grande—we have a turbidity rod that we run down into the water till we cannot see the platinum wire at the end of it—that he stood the stick up, and if it tipped over he called it water; if it did not tip over he called it mud. The sum of the two columns, Suspended Matter and Total Dissolved Solids, represents the total mineral matter in the water, both suspended and dissolved.

S. P. Stevenson.—What is the matter in solution and what is the composition of the mud?

R. B. Dole.—I think I can tell you approximately. The average of analyses on the Brazos River shows that it contains 116 parts per million of calcium, 226 parts of alkalies, 262 parts of sulphates (SO_4), and 331 parts of chlorine. Therefore its mineral content is principally the chlorides and sulphates of sodium and potassium, with undoubtedly a considerable percentage of sulphates of lime and magnesia and a normal amount of bicarbonates (HCO_3) in the same manner. The suspended matter we do not analyze, because as a general rule in a manufacturing plant, since that causes the most trouble, there is some provision for removing it either by sedimentation or by filtration; therefore it does not make much difference what it is composed of, because it is removed.

No. 48.

HEAT TRANSFER IN COOLERS AND CONDENSERS OF THE DOUBLE PIPE TYPE.

By R. L. Shipman, Ithaca, N. Y.

(*Member of the Society.*)

The subject of refrigerating machines seems to have been somewhat overworked for some years, the gains made by the alteration of design and methods of operation of these machines being comparatively small. In fact, no remarkable gains over the records of the best machines of today are to be expected from this source of investigation.

The subjects of coolers and condensers of refrigerating systems seem to have been comparatively neglected. For that reason it is thought advisable to give some results of recent theoretical and experimental investigations of these very important and interesting elements of a refrigerating system. The thanks of this Society and the profession are due in general to the York Manufacturing Company, of York, Pa., and in particular to Mr. Thomas Shipley, vice president and general manager of that company, for this contribution to the literature upon the subject of refrigerating engineering.

It has apparently been the custom to consider coolers and condensers as very simple forms of apparatus, unsusceptible to variations in efficiency due to different designs and different methods of operation. A careful study of the data given in this paper will show this conclusion to be erroneous. It seems highly probable that there are far greater gains to be obtained in refrigerating systems by proper designs and correct methods of operating coolers and condensers than are to be obtained from any change in design or methods of operation of the refrigerating machine.

In the first place, it has been pretty thoroughly demonstrated that the amount of heat passing through a given surface in a given time is directly proportional to the difference in temperature between the two sides of the surface. Then, if it is desired to transmit a given quantity of heat, (H) 12,000 B. T. U., in a given time, one

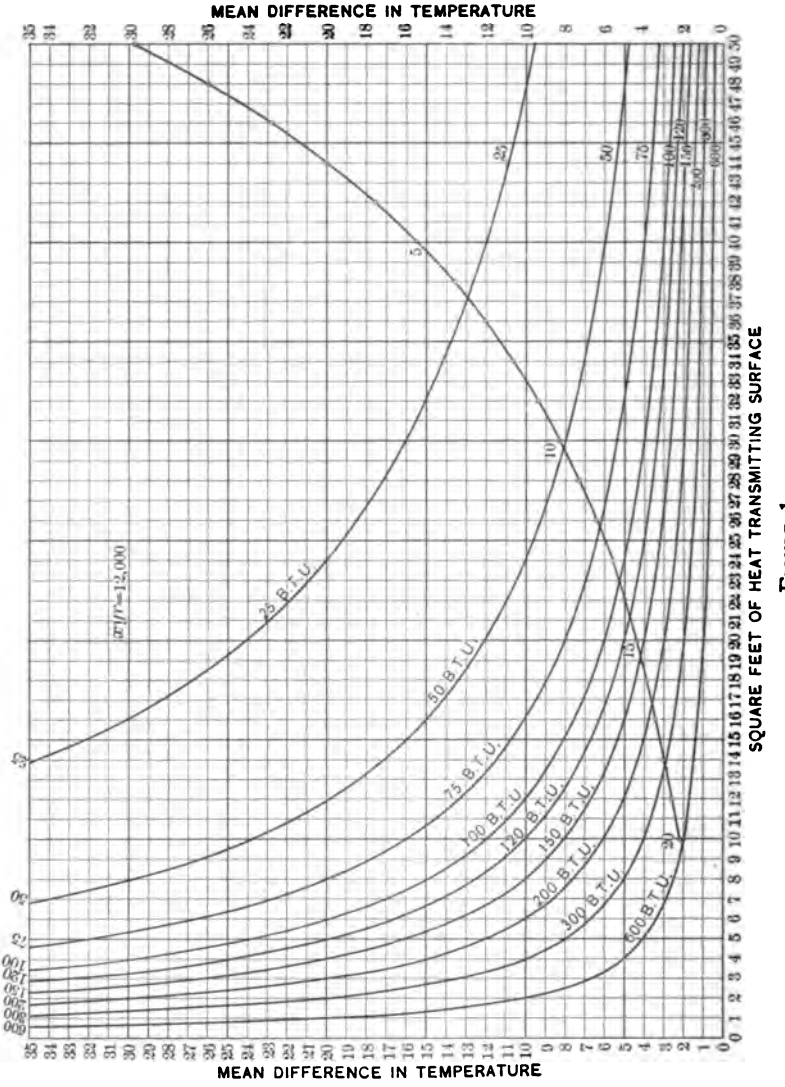
MEAN DIFFERENCE IN TEMPERATURE
SQUARE FEET OF HEAT TRANSMITTING SURFACE
MEAN DIFFERENCE IN TEMPERATURE
25 B.T.U.
50 B.T.U.
75 B.T.U.
100 B.T.U.
120 B.T.U.
150 B.T.U.
200 B.T.U.
300 B.T.U.
600 B.T.U.

FIGURE 1.

hour, at a given rate (r) of heat transfer, 100 B. T. U. per square foot per hour per degree mean difference in temperature, through a given amount of surface, x, it would require a given mean difference in temperature, y. Then $x\ y\ r = H$, and with a constant rate of heat transfer, r, the product of x and y must be a constant quantity and their values will vary as the co-ordinates to a rectangular hyperbola. A rectangular hyperbola can be constructed showing the relation between these two quantities for a given quantity of heat to be transferred at a given rate. If the rate of heat transfer is changed it will change the position of the curve, but the curve will still be a rectangular hyperbola asymptotic to the same axes.

Fig. 1 is a series of such curves showing the relation between these four quantities, for which the quantity of heat has been taken as 12,000 B. T. U., which is the amount of heat to be handled per hour per ton of refrigeration, and the values on the horizontal scale show the amount of surface to be supplied per ton of refrigeration, while the vertical scale shows the mean difference in temperature between the two sides of the surface.

A very important lesson to be learned from a study of this chart is that when we go to either extreme it takes a large change in one of the variable quantities to create a comparatively small change in the other variable quantity. These extremes are usually to be avoided in the design of a refrigerating system. Take, for example, the 100 B. T. U. curve. For a mean difference of 10° it would require 12 square feet of surface per ton, while for a mean difference of 5° it would require the addition of 12 square feet of surface per ton, and for a reduction of 2½° degrees more it would require the addition of 24 square feet per ton, and to reduce the mean difference still another 1¼° would require the addition of 48 square feet, and for a mean difference of only 1° it would require a total of 120 square feet of surface per ton.

Table I has been plotted from this curve, and is adapted especially to the design of freezing tank coils, the brine in these tanks being kept at some constant temperature above the temperature of the ammonia in the coils. Any number of such tables for different rates of heat transfer could be constructed from Fig. 1. But as this table is constructed for the rate of 100 B. T. U. it is easy to get the required surface for any other rate of heat transfer by multiplying that obtained from this table by the ratio of 100 to the new rate of heat transfer. For example, if it is required to make ice with 16° brine in a freezing tank and a 10° mean difference (M. D.), and the suction pressure of 20 pounds and the rate of heat transfer for a given con-

GROSS HORSE POWER REQUIRED TO PRODUCE ONE TON REFRIGERATION							SUCTION PRESSURE, POUNDS GAUGE	CORRESPONDING TEMPERATURE, DEG. FAHR.	FOR HEAT TRANSFER AT RATE OF 100 B.T.U. PER SQUARE FOOT OF PIPE SURFACE PER HOUR PER DEGREE MEAN DIFFERENCE OF TEMPERATURE, TEMPERATURE OF BRINE, DEGREES FAHR.																													
CONDENSING PRESSURES, POUNDS GAUGE									30°		24°		20°		16°		12°		10°		8°		6°		4°		2°		0°		−4°		−8°		−14°		−20°	
135	150	165	185	195	210	225			M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.	M.D.	S.
.70	.78	.88	1.00	1.06	1.14	1.24	44.72	30																														
.73	.82	.91	1.04	1.10	1.18	1.28	42.26	28	2	60																												
.77	.86	.95	1.08	1.13	1.22	1.32	39.89	26	4	30																												
.81	.89	.99	1.12	1.18	1.26	1.36	37.60	24	6	20																												
.84	.94	1.03	1.16	1.22	1.30	1.41	35.39	22	8	15	2	60																										
.88	.98	1.07	1.20	1.26	1.35	1.46	33.25	20	10	12	4	30																										
.92	1.02	1.12	1.25	1.31	1.40	1.51	31.19	18	12	10	6	20	2	60																								
.97	1.06	1.16	1.30	1.36	1.45	1.56	29.20	16	14	8.5	8	15	4	30																								
1.01	1.10	1.20	1.34	1.40	1.50	1.60	27.28	14	16	7.5	10	12	6	20	2	60																						
1.06	1.15	1.25	1.38	1.45	1.55	1.65	25.43	12	18	6.7	12	10	8	15	4	30																						
1.09	1.20	1.30	1.43	1.50	1.60	1.70	23.64	10	20	6.0	14	8.5	10	12	6	20	2	60																				
1.14	1.24	1.34	1.46	1.54	1.64	1.75	21.93	8	22	5.5	16	7.5	12	10	8	15	4	30	2	60																		
1.18	1.28	1.39	1.53	1.59	1.70	1.80	20.27	6	24	5.0	18	6.7	14	8.5	10	12	6	20	4	30	2	60																
1.22	1.32	1.44	1.58	1.64	1.75	1.85	18.66	4	26	4.6	20	6.0	16	7.5	12	10	8	15	6	20	4	30	2	60														
1.27	1.37	1.49	1.64	1.70	1.81	1.91	17.14	2	28	4.3	22	5.5	18	6.7	14	8.5	10	12	8	15	6	20	4	30	2	60												
1.31	1.42	1.53	1.68	1.74	1.86	1.96	15.67	0	30	4.0	24	5.0	20	6.0	16	7.5	12	10	10	12	8	15	6	20	4	30	2	60										
1.36	1.47	1.58	1.74	1.80	1.91	2.02	14.25	−2	32	3.8	26	4.6	22	5.5	18	6.7	14	8.5	12	10	10	12	8	15	6	20	4	30	2	60								
1.41	1.52	1.63	1.80	1.85	1.97	2.07	12.89	−4	34	3.6	28	4.3	24	5.0	20	6.0	16	7.5	14	8.5	12	10	10	12	8	15	6	20	4	30								
1.46	1.57	1.69	1.85	1.91	2.03	2.14	11.57	−6	36	3.4	30	4.0	26	4.6	22	5.5	18	6.7	16	7.5	14	8.5	12	10	10	12	8	15	6	20	2	60						
1.51	1.62	1.74	1.91	1.96	2.09	2.20	10.31	−8	38	3.2	32	3.8	28	4.3	24	5.0	20	6.0	18	6.7	16	7.5	14	8.5	12	10	10	12	8	15	4	30						
1.56	1.67	1.79	1.96	2.01	2.14	2.26	9.10	−10	40	3.0	34	3.6	30	4.0	26	4.6	22	5.5	20	6.0	18	6.7	16	7.5	14	8.5	12	10	10	12	6	20	2	60				
1.61	1.72	1.84	2.01	2.07	2.20	2.31	7.94	−12	42	2.8	36	3.4	32	3.8	28	4.3	24	5.0	22	5.5	20	6.0	18	6.7	16	7.5	14	8.5	12	10	8	15	4	30				
1.65	1.77	1.88	2.06	2.12	2.25	2.37	6.83	−14	44	2.7	38	3.2	34	3.6	30	4.0	26	4.6	24	5.0	22	5.5	20	6.0	18	6.7	16	7.5	14	8.5	10	12	6	20				
1.71	1.84	1.95	2.12	2.18	2.31	2.43	5.76	−16	46	2.6	40	3.0	36	3.4	32	3.8	28	4.3	26	4.6	24	5.0	22	5.5	20	6.0	18	6.7	16	7.5	12	10	8	15	2	60		
1.76	1.89	2.00	2.17	2.24	2.37	2.49	4.73	−18	48	2.5	42	2.8	38	3.2	34	3.6	30	4.0	28	4.3	26	4.6	24	5.0	22	5.5	20	6.0	18	6.7	14	8.5	10	12	4	30		
1.81	1.93	2.06	2.22	2.30	2.43	2.55	3.75	−20	50	2.4	44	2.7	40	3.0	36	3.4	32	3.8	30	4.0	28	4.3	26	4.6	24	5.0	22	5.5	20	6.0	16	7.5	12	10	6	20		
1.86	1.98	2.10	2.28	2.35	2.48	2.60	2.80	−22	52	2.3	46	2.6	42	2.8	38	3.2	34	3.6	32	3.8	30	4.0	28	4.3	26	4.6	24	5.0	22	5.5	18	6.7	14	8.5	8	15	2	60
1.92	2.03	2.16	2.33	2.41	2.53	2.66	1.91	−24	54	2.2	48	2.5	44	2.7	40	3.0	36	3.4	34	3.6	32	3.8	30	4.0	28	4.3	26	4.6	24	5.0	20	6.0	16	7.5	10	12	4	30
1.96	2.08	2.20	2.39	2.47	2.59	2.70	1.05	−26	56	2.17	50	2.4	46	2.6	42	2.8	38	3.2	36	3.4	34	3.6	32	3.8	30	4.0	28	4.3	26	4.6	22	5.5	18	6.7	12	10	6	20
2.00	2.12	2.25	2.43	2.51	2.62	2.74	.22	−28	58	2.1	52	2.3	48	2.5	44	2.7	40	3.0	38	3.2	36	3.4	34	3.6	32	3.8	30	4.0	28	4.3	20	5.0	20	6.0	14	8.5	8	15
2.02	2.13	2.26	2.44	2.53	2.64	2.76	−.57	−30	60	2.0	54	2.2	50	2.4	46	2.6	42	2.8	40	3.0	40	3.2	36	3.4	34	3.6	32	3.8	30	4.0	26	4.6	22	5.5	16	7.5	10	12

TABLE I.

struction is 20 B. T. U. per hour per square foot per degree difference in temperature, it would take $12 \times \frac{100}{20} = 60$ square feet per ton.

But if we have a brine cooler in which there is a considerable range in temperature in the brine, the chart and table will not apply directly, and it becomes necessary to construct others to meet the conditions. For example, in the case of a double pipe brine cooler, the ammonia in the coils remains practically at a constant temperature, while the brine is reduced in temperature on its passage through the cooler. It seems quite a common belief that the law of this change in temperature is shown by a straight line, as the straight line between A and D, in Fig. 2, and that the mean difference in temperature would be the ordinate connecting the centre of B C with the centre of A D. But this is not the case, as such a variation in temperature would mean that equal amounts of surface of the pipe would transmit equal quantities of heat in the same time irrespective of the difference in temperature between the two sides of the surface

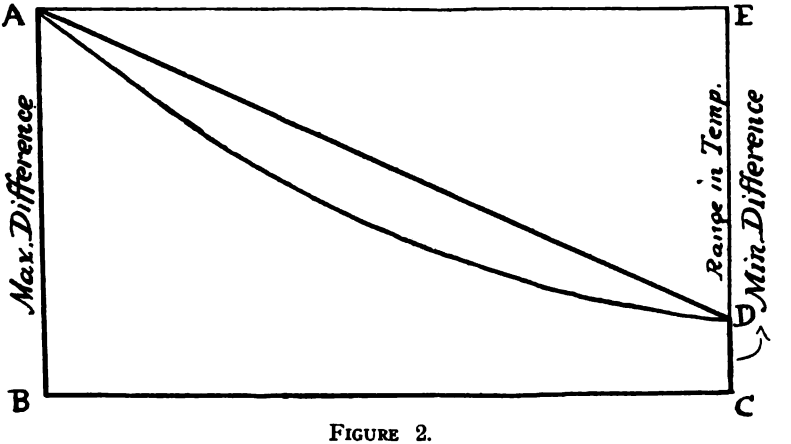

FIGURE 2.

But it can be easily shown that in the general case the average or mean difference in temperature

$$\text{M. D.} = \frac{\text{Range in Temperature}}{\log_{.2} \dfrac{\text{Maximum Difference}}{\text{Minimum Difference}}}$$

and the temperature line is a curve passing through A and D and all other points in the curve falling below the straight line passing through these two points.

TABLE II.

80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	(T_p-T_e)
40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	
		40	45	50	55	60	65	70	75	80	85	90	95	100	105	
			40	45	50	55	60	65	70	75	80	85	90	95	100	
				40	45	50	55	60	65	70	75	80	85	90	95	
					40	45	50	55	60	65	70	75	80	85	90	
						40	45	50	55	60	65	70	75	80	85	
							40	45	50	55	60	65	70	75	80	
								40	45	50	55	60	65	70	75	
									40	45	50	55	60	65	70	
										40	45	50	55	60	65	
											40	45	50	55	60	
												40	45	50	55	
													40	45	50	
														40	45	50

Range in Temp. — Mean Diff.

Mean Difference $= \dfrac{(T_s-T_e)}{\log_e \dfrac{(T_p-T_e)}{(T_p-T_d)}}$

Temperature of Condensing Water { Entering, T_e / Discharge, T_d

T_p = Temperature Corresp. to Cond. Pressure.

T_e — Cond. Temp. — Cond. Press. — Gauge — T_d

| T_e | Gauge | T_d | | | | | | | | | | | | | |

By the use of this formula the mean differences of temperature of Table II were computed and the values were checked by plotting the values on cross-section paper, and these values produced the curves of Fig. 3. From this chart an indefinite number of tables similar to Table II and Table V can be plotted. The mean differences in temperature of Table V were read directly from Fig. 3. In Fig. 3 the lines slightly curved and slanting to the right represent the smaller differences in temperature, the vertical scale representing ranges in temperature and the horizontal scale representing mean differences in temperature. Having only the smaller difference and the range in temperature, the mean difference can be read direct from the figure.

In illustration:

Example 1. Range 20°, smaller difference 5°. Trace the line marked 20 horizontally to the right until it intersects the slanting line marked 1, and vertically below this point of intersection read the mean difference 6.5° on the horizontal scale.

Example 2. Range 50°, smaller difference 5°. Trace horizontal line marked 50 to the right until it intersects slanting line marked 5. and vertically below this point of intersection read the mean difference 20.75° on the horizontal scale, etc.

In Table V the vertical column of numbers to the left of the table, headed $(T_d - T_p)$, is a column of smaller differences in temperature, in the section of double numbers to the right the larger numbers are ranges in temperature, and the smaller numbers imme-

TABLE III.

One and one-quarter-inch Pipe, Twelve Pipes High.

Total length of Pipe about 220 feet.

1 Velocity of Water in Coils, Feet per Minute.	2 Differential Pressure, Pounds per Square Inch.	3 Water Discharged, Gallons per Minute.	4 B. T. U. per Hour per Square Foot per Degree Mean Difference in Temperature.	5 Tons Refrigeration per Degree Mean Difference in Temperature.
100	2.28	7.64	150	1.00
150	5.75	11.4	198	1.35
200	9.98	15.5	240	1.60
250	15.00	19.2	260	1.80
300	21.60	22.2	300	2.00
400	37.80	30.5	338	2.25
500	55.00	38.2	...	....
600	.....	45.7	...	....
700	.....	53.5	...	....
800	.....	61.0	...	....

NOTE.—Table III is to be considered only approximately correct except for columns 1 and 3. The other columns were derived by careful experiments on standard condensers, but depend upon special features of construction.

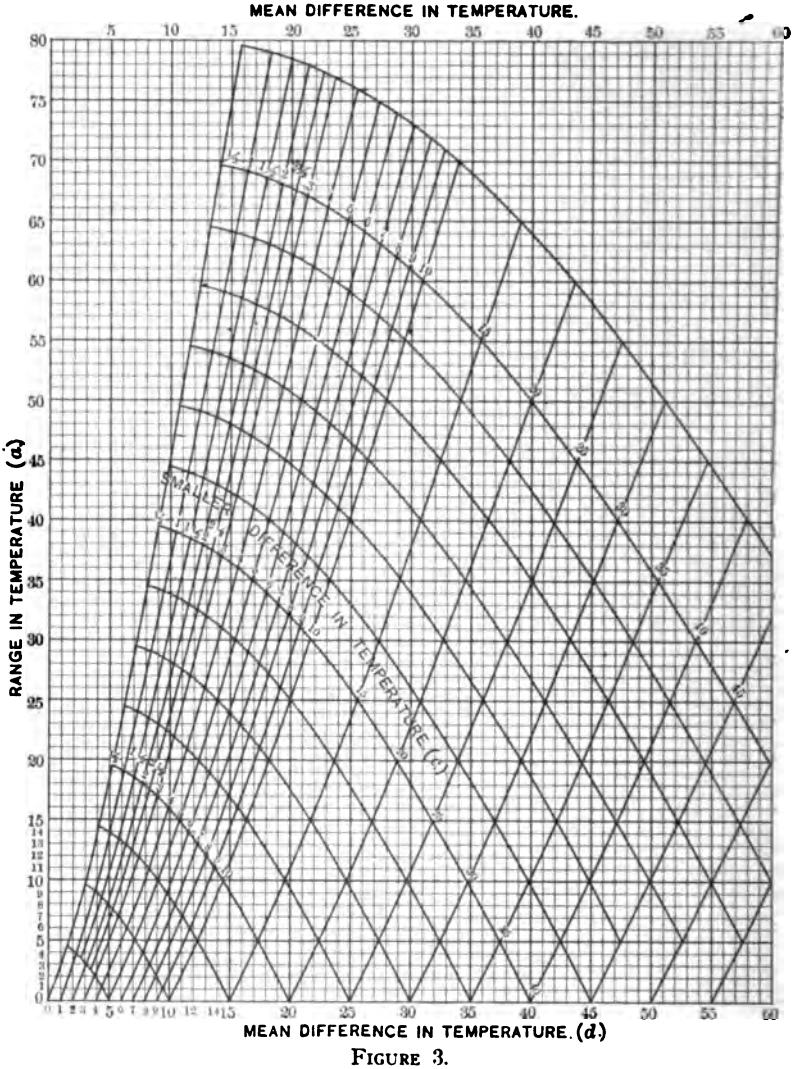

FIGURE 3.

diately under the larger numbers in the same square are corresponding mean differences in temperature.

In illustration:

Example 1. If the smaller difference is 1 and the range is 50, the mean difference is 12.7.

Example 2. If the smaller difference is 5 and the range is 10, the mean difference is 9.1, etc.

All of these numbers are independent of the construction outside

TABLE IV.

Two-inch Pipe, Twelve Pipes High

Total length of Pipe about 220 Feet.

1	2	3	4	5
Velocity of Brine in Coils, Feet per Minute.	Differential Pressure, Pounds per Square Inch.	Brine Discharged, Gallons per Minute.	B. T. U. per Hour per Square Foot per Degree Mean Difference in Temperature.	Tons Refrigeration per Degree Mean Difference in Temperature.
100	2.2	17.5	95	1.00
150	3.7	23.8	112	1.18
200	5.7	35.0	130	1.37
250	8.4	43.8	145	1.53
300	11.4	53.0	158	1.67
400	18.8	70.0	177	1.87
500	28.2	88.0	191	2.00
600	39.4	105.0	205	2.16
700	52.2	123.0	215	2.26
800	80.0	140.0	220	2.30

NOTE—Table IV is to be considered only approximately correct except for columns 1 and 3. The other columns were derived by careful experiments on standard coolers, but depend upon special features of construction.

of this section. The construction outside of this section has been made for suction temperatures from — 25° to + 40°, varying by increments of 5°. This could be easily filled in for every degree difference in suction temperature, but it would require four lines added where there is one in the present construction. As can be seen in the upper left-hand section of this table, construction is made for initial temperature of brine from 91° to — 23°. The lower right-hand section shows discharge temperatures of brine for conditions in the same cycle. A cycle in this table is bounded by five numbers: the range and mean difference in temperature at the lower left-hand corner; the initial temperature of the brine at the upper left-hand corner of the cycle; the suction temperature to the upper right hand; and the discharge temperature of the brine in the lower right-hand corner of the cycle.

In illustration:

Example 1. Range of 10° with its associated mean difference in temperature of 9.1° may be taken as the lower left of a cycle; any initial temperature of brine vertically above it, as + 10°, may be taken as the upper left; the — 5° suction temperature between the same lines to the right forms the upper right-hand number of the cycle; and the zero temperature of discharge brine forms the lower right-hand number of the cycle. A line connecting these five numbers

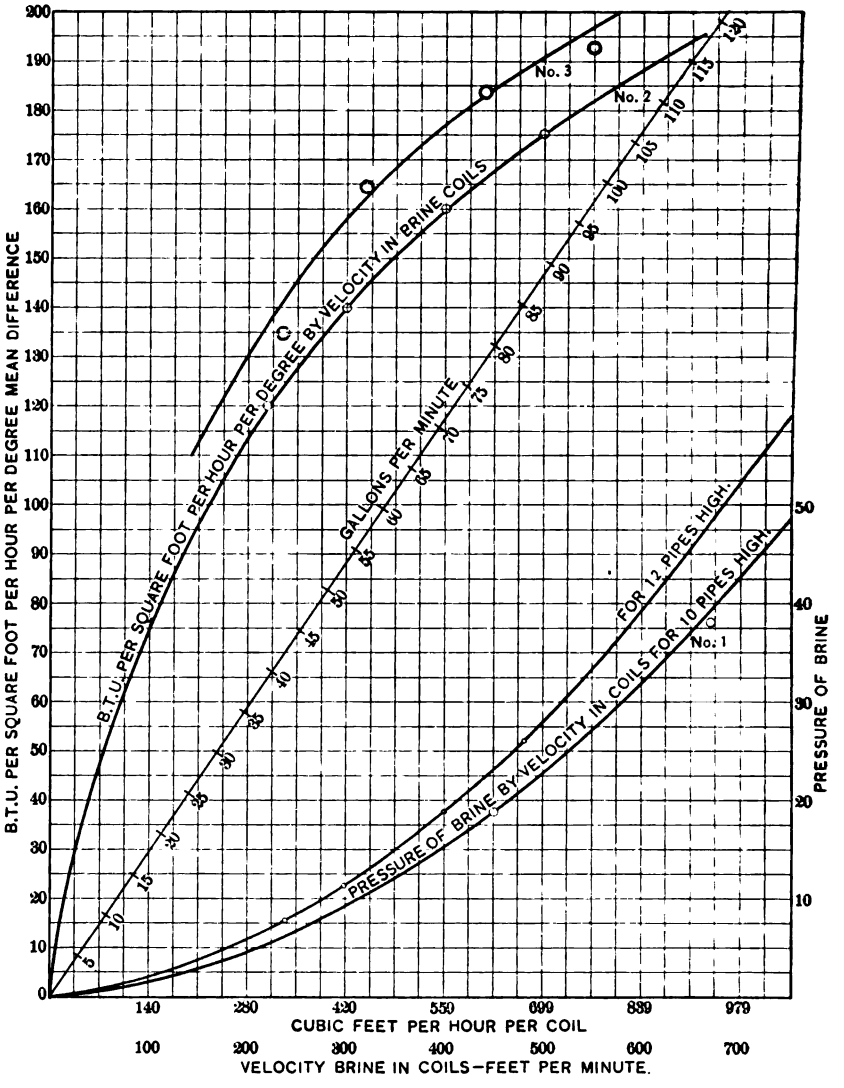

FIGURE 4.

would form a loop, rectangular in form with the exception of the portion that passes through the suction temperature. By the use of the mean difference thus found and Fig. 1, the number of square feet of cooling surface can be found to meet these temperature conditions, provided we know the rate of heat transfer. This rate of heat transfer is a widely variable quantity, dependent upon several condi-

TABLE V.

| (T_d-T_p) | | |

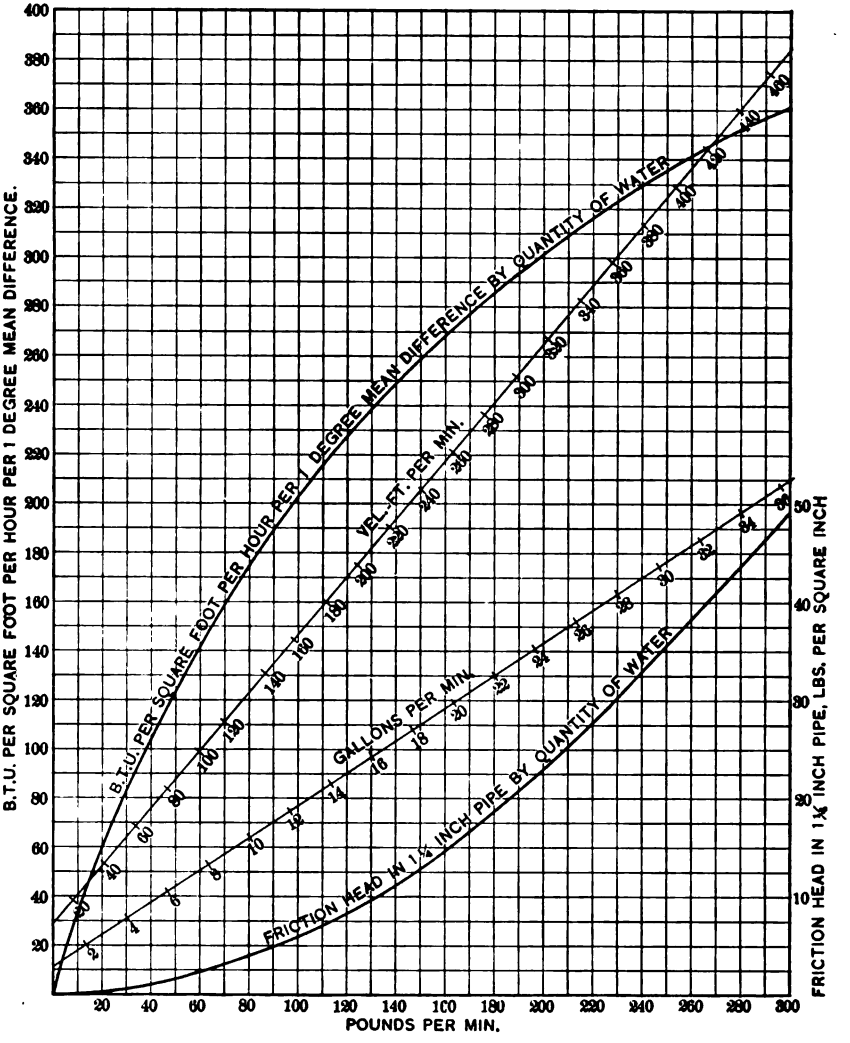

FIGURE 5.

tions, and a great deal of experimental investigation has been carried on at the York testing plant to determine this rate of heat transfer for a great variety of conditions, and Table IV sets forth some good average results for the double pipe cooler ten and twelve pipes high.

Fig. 4 shows graphically some very interesting experimental data also derived at the York testing plant. The two curves in the lower right-hand section show the pressures necessary to force the brine

through the coils at the velocities shown on the horizontal scale. The No. 2 curve in the upper left-hand section of the chart shows the rates of heat transfer through the pipe surface for these same velocities represented on the horizontal scale.

The diagonal scale shows the number of gallons per minute that will be passing through the 1¼-inch pipe at the velocities of the horizontal scale.

Tables II and III and Fig. 5 show for the double pipe condenser what Tables IV and V and Fig. 4 show for the double pipe brine cooler, and the same general discussion applies to both sets of data.

DISCUSSION.

R. L. Shipman.—I may say that this work is, of course, especially for the designing engineer, but can be used to a considerable extent by the operating engineer.

Louis Block.—I do not know whether you mentioned it, but I would like to know what your heat transfer was per square foot of surface, and the mean difference of temperature which you found for the various speeds of water in the cooler?

R. L. Shipman.—It is given in detail in the charts and tables. There is nothing indefinite or vague about it. The numbers are given in all the scales.

No. 49.

Discussion of the Topic—STANDARDIZING OF MEASURING INSTRUMENTS.

Chairman Starr.—I would like to introduce for discussion the subject of gauges, hydrometers and other measuring instruments in common use. It has always seemed to me that our pressure gauge, starting at the atmosphere with a zero, was a very bad thing; that it would be better if all gauges started on the absolute zero or no pressure. I have noticed that with the average operating engineer the fact that our pressure gauge starts at the atmosphere generally leads him sooner or later into the idea that a vacuum does something. We also have a great variety of hydrometer scales in our measurements of the gravity of ammonia and brine and other liquids which we use. Some of these scales are absolutely arbitrary and seem to have no particular reason for their existence. It would seem that a simple specific gravity scale would suit all conditions and be a much easier and more definite proposition for the engineer.

James Ely.—The Chairman has brought up a very important subject. We find the Baumé scale is generally used, but has no less than eight distinguishable standards, i. e., the original Baumé has been entirely lost sight of. Different manufacturers have practically their own standards, covering not only the Baumé scale but all the other hydrometer scales. This condition has partly come about from the fact that at Charlottenburg, Germany, standards have been issued and imported for many years; they in time have changed their standards somewhat, in the meantime manufacturers have continued to use the standard originally imported. There is now at Washington a Bureau of Standards which has laid out hydrometer scales according to what will be the standard in America, regardless of any of the so-called standards in the market. It would hardly be possible to eliminate entirely the Baumé scale, as the specific gravity scale carries so many more figures, but, the Government having furnished us with a modulus, we have been able to determine and standardize the Baumé scale, which, although, as our Chairman says, not simple in one sense of the word, is simple in another, and many tables have been based on that scale which would cause an endless amount of trouble to transfer to the specific gravity scale. It would be a wise

move on our part if a committee was appointed to confer with the National Bureau of Standards and report to the Society just what it had adopted in the way of standard hydrometers. I believe the Manufacturing Chemists' Association has already taken up the matter with the Government and is using instruments that are in accord with Government standards.

W. H. Bower.—I think I can throw some light on this subject. I was chairman of the committee appointed by the Manufacturing Chemists' Association to make a standard for hydrometers, to agree on a modulus for the Baumé scale and also to make standard tables for the well-known mineral acids and aqua ammonia. The chemical work was all done in the laboratory of the General Chemical Company and was checked up by Professor Talbot, of the Massachusetts Institute of Technology. After three years' work we were able to get these tables out, and they have been accepted as standard. The modulus agreed on was 145 for the Baumé scale for liquids heavier than water at a temperature of 60° Fahr. For aqua ammonia or liquids lighter than water, the scale beginning at 10 equals water, the formula is $(140 \div \text{Sp. Gr.}) - (140 - 10)$. If the Society desires these tables for aqua ammonia they can be procured of the secretary of the Manufacturing Chemists' Association in Philadelphia. This standardization has been of great value to all chemical manufacturers who have gotten as far as we have, because there were any number of standards used all over the country. If you go to the instrument makers they will make an instrument according to the standard of the Manufacturing Chemists' Association, which has been accepted by the chemists as a standard.

H. D. Stratton.—How is that standard in relation to the Government standard?

James Ely.—It is the Government standard. The Government has carried its investigation on this subject much further than is possible for any manufacturer. It is at present working on a table to give us the corrections according to the surface tension to the glass.

Chairman Starr.—I would like to ask the gentleman, why use a hydrometer scale, an arbitrary scale, one starting at 10 and another starting somewhere else? Why not a direct specific gravity reading which would, it seems to me, cover the whole case?

James Ely.—It is much easier to remember a certain number like 10, 20 or 30, than it would be to remember the number covering a specific gravity reading which would be 1.225. Then again we cannot eliminate the Baumé scale entirely, for it is as well known

as the specific gravity, and it would be just as easy to eliminate the Fahrenheit scale and use the centigrade only, or to adopt the metric system.

Chairman Starr.—In other words, it is a matter of custom that it is hard to overcome?

James Ely.—*Yes.*

H. Dannenbaum.—There is no difference; all hydrometers for liquids heavier than water start with 0° Baumé and hydrometers for liquids lighter than water start with 10° Baumé.

Chairman Starr.—For ammonia?

James Ely.—For ammonia and all liquids lighter than water the Baumé scale starts at 10° and liquids heavier than water start at 0° Baumé.

Chairman Starr.—But there are so many other scales?

James Ely.—There are, but the Baumé and specific gravity scales are the two most commonly used in this country.

R. L. Shipman.—The suggestion that gauges be started at absolute zero would make it impossible to read what we call the gauge pressure, because the zero would always be changing. If we had a gauge with an absolute zero scale it would be necessary to have a scale which would be movable, so that we could set the zero of the movable scale at the pressure indicated by the barometer; then the true gauge pressure could be read direct.

W. E. Parsons.—Why would it not be an improvement to leave the stop pin off the scale, so that when the index hand goes back you would know where the pressure is going to and could still let the zero point be at atmospheric pressure? If the gauge is correct the hand ought to go back to zero every time and not require a pin to keep it from going to another place.

R. L. Shipman.—That would probably be an improvement and would prevent many errors from incorrect gauges. Ammonia gauges do not have pins, as they are always used as compound gauges, but a pressure gauge cannot be used to indicate the true atmospheric pressure, as it will always come to the same zero whatever the barometric pressure. But since pressure gauges cannot be depended upon to register within a pound or two of the correct pressure, it seems hardly necessary to correct for changes of barometer when gauges alone are used for pressure readings. It might be an improvement in gauge construction, especially for ammonia, to put both the absolute zero scale and the gauge scale on the face of the gauge.

G. T. Voorhees.—I want to go back to the subject of hydrometers. I spent nearly two months this summer in corresponding

with most of the manufacturers of ammonia and tried to find what a standard degree Baumé was equal to in per cent of ammonia, and I discovered all these different kinds of scales, how they varied, and how the degree Baumé was generally accepted. Some of the leading manufacturers of ammonia would not even accept the standard set by the chemists; that is, a degree Baumé does not signify a certain percentage of ammonia in our work when we use aqua ammonia. I do not care anything about Baumé degrees. I want to know the percentage of ammonia in the solution and I am going to have some scales built for me that will read directly on the hydrometer the percentage of ammonia of the solution, because as hydrometers are now built you have to refer back to your table. Take your Baumé degree with the liquid at 60° Fahr. You want to know the percentage of ammonia in your solution. This is only a step from which you have got to go back to your tables, whereas with a percentage scale on the hydrometer you have the result desired at once. For any accurate work on aqua ammonia you cannot use the floating hydrometer at all; you have got to use Westphal's balance, as the floating hydrometer is not accurate enough and the element of the personal equation of the observer is too uncertain with the floating hydrometer.

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